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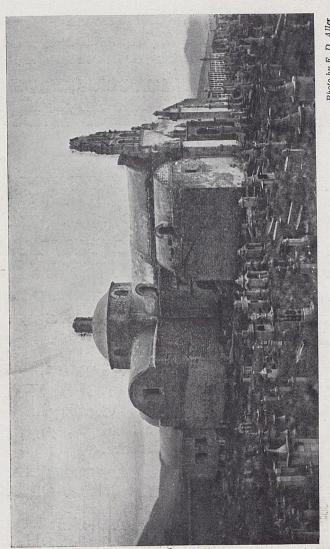


Photo by F. D. Aller.

Church of San Bernardo, Potosí (Bolivia), where Padre Barba Preached.



# ARTE

## DE LOS METALES,

EN QUE SE ENSEÑA

EL VERDADERO BENEFICIO

DE LOS DE ORO, Y PLATA POR AZOGUE.

EL MODO DE FUNDIRLOS TODOS,

Y COMO SE HAN DE REFINAR,

Y APARTAR UNOS DE OTROS.

COMPUESTO

POR EL LICENCIADO ALVARO
Alonso Barba, natural de la Villa de Lepe,
en la Andalucia, Cura en la Imperial
de Potosì de la Parroquia
de San Bernardo.

NUEVAMENTE AHORA AÑADIDO.

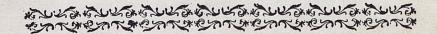
CON EL TRATADO DE LAS ANTIGUAS MINAS

de España.que escribió Don Alonso Carrillo y Laso,

Caballero del Avito de Santiago, y

Caballerizo de Cordova.

CON LICENCIA. EN MADRID, EN LA OFICINA de la Viuda de Manuel Fernandez. A costa de Manuel de Godos, Mercader de Libros en esta Corte. Se ballarà en su Tienda en las Gradas de San Phelipe el Real.



## EL ARTE DE LOS METALES

(METALLURGY)

Translated from the Spanish of ALVARO ALONZO BARBA

BY

ROSS E. DOUGLASS

E. P. MATHEWSON



texto on layles

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#### **PREFACE**

"El Arte de los Metales," literally "The Art of the Metals," (Metallurgy) written in Spanish by Alvaro Alonso Barba, Master of Arts, and Curate of the Parish of San Bernardo, Potosí, Bolivia, is undoubtedly the earliest published work on American Metallurgy. Originally presented as a report to the Crown representative, it was warmly approved, in 1637, by the Deputies of the Royal Village of Potosí and the Amalgamators' Guild, and by them recommended to the Crown for publication.

Book One summarizes the geological knowledge of Barba's time, but Books Two to Five, inclusive, are based on the knowledge acquired by him in many years of active work in mining and ore treatment, in a region which, even before his time, had yielded many millions of dollars in silver bullion. The excellent work done by the old Spanish metallurgists is well known to many engineers of this generation who have had occasion to sample and assay old Bolivian waste and tailings dumps.

Barba's work was first published in Spain in 1640, and reprinted in 1675 and 1729. Edward Montagu, Earl of Sandwich, Ambassador Extraordinary to Spain, translated the first two books into English in 1669; the translation is of little value, as he lacked technical knowledge. German translations and reprints appeared in 1676, 1696, 1726, 1739, 1749 and 1767; French translations and reprints appeared in 1730, 1751 and 1752. Three Spanish reprints, published in Peru, Bolivia and Chile, contain many errors. To the best of our knowledge, only three copies of the Madrid quarto edition of 1640, said to have been banned and burned by the

Inquisition, are in existence; and they are owned by the British Museum. Our translation is made from the Madrid Edition of 1729, which we have had compared with the Museum copies, and which has been found to be substan-

tially correct.

In the First Book, Barba uses many Latin mineralogical terms taken from Pliny, Dioscorides, Strabo, Galen and other authors. We have found the Latin mineralogy of Encelius, "De Re Metallica" (published five years before Agricola's work appeared), to be of great help in translating the First Book of Barba. Many years' professional work in South America has familiarized us with local Spanish mining terms, which in many cases have survived since the bonanza days of Potosí. Our aim has been to reproduce faithfully the phraseology of the author; where the English has suffered we beg the indulgence of the reader. We have thought it best to omit footnotes in order to make a small and reasonably priced volume.

As fervent admirers, we dedicate this translation to the memory of "Padre" Barba, and recommend it to all interested in the history of early Spanish industrial achievements in South America, as well as to students of the progress of

metallurgy.

(Signed)

R. E. D. E. P. M.

New York, December 1, 1922.

RECOMMENDATION OF THE ROYAL COMMISSION OF POTOSÍ, APPOINTED BY SEÑOR DON JUAN LIZARÁN

We, Diego de Padilla, Royal Ensign and Mayor of this Royal Village of Potosí, and Don Andres de Sandoval and Bernardo de Ureña, as members and representatives of the Amalgamators' Guild of this Village, by order of Señor Don Juan de Lizarán of His Majesty's Council, and President of the Royal Audience of La Plata, have reviewed the "Treatment, or Art of Treating Ores," written by Alvaro Alonso Barba, Curate of the Parish of San Bernardo, this



Village. We judge it to be a Work worthy of the reputation that the writer has had in these parts for many years. It is a service of the greatest importance to His Majestv, and a benefit beyond recompense to all his Vassals in these Kingdoms. We recognize, by the author's discussion, his many years' experience in the subject. For the damages we have suffered in the loss of Quicksilver, and the failures to extract all the values in the ores, we see the causes and remedies pointed out so definitely that, although many individuals have not been able so far, due to lack of time, to follow his advice, we do not doubt his conclusions: especially so when we take into consideration the authority of the Writer, never doubted by those who know him. is a work all the more worthy of Reward when it is considered that the Author, without waiting for agreements of any sort, now publishes it. The sum of his merits is such that His Majesty may well reward him. And it is thus we feel, and sign, in Potosí, the fifteenth of March, 1637.

(Signed) Diego Padilla.
D. Andres de Sandoval.
Bernardo de Ureña.

By order of His Majesty I have reviewed this book, entitled "Arte de los Metales," composed by Alvaro Alonso Barba, and I consider it useful and advantageous that it be printed.

D. Paulo de Barondelet.

MADRID, September 28, 1639.





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#### FIRST BOOK

OF

## EL ARTE DE LOS METALES

(Metallurgy)

THE MANNER IN WHICH ORES ARE BEGOTTEN AND THE THINGS THAT ACCOMPANY THEM

#### CHAPTER ONE

THE THINGS THAT ARE BEGOTTEN WITH THE ORES, AND, FIRSTLY, THE EARTH AND HER COLOURS

Metals, Stones, Earth, and the substances called Salts are the four Classes to which can be consigned all the inanimate substances formed by the Earth in her entrails. Nature creates them mixed and associated, and, because the treatment of Metals cannot be practised without a knowledge of the other three Classes, as will be seen from the precepts, I shall treat briefly of them. Here Earth is not to be understood as that simplicity, one of the four Elements which, as the common school of Philosophers have claimed, cover all of the sublunar mixtures; nor is it so complex that it partakes of a Metal, Copperas, Saltpetre, or other Salts; rather is it that, which, lacking all these, neither melts nor separates in water or fire like the Salts or Ores; neither is it massive and hard like the Stones.

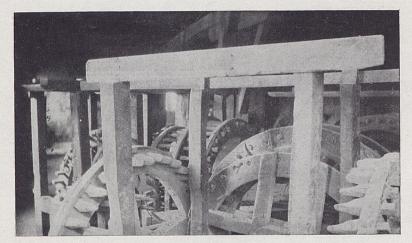
Some attribute to Aristotle the saying that pure elemental Earth has no colour whatsoever. Straton Lampasceno affirmed that it should be white, because this Colour



can be seen in Ashes. Nevertheless, he who seeks for Ores may rest secure that, however deep he may sink his Mines, he will never encounter this class of earth, pure and unadulterated, which might constrain him to essay new proofs and experiences. Such does not exist in the World, by reason of the great and continuous Mixing which the Elements have suffered and still do suffer. The Colour of the simplest to be found, or least altered, as Cardona would have it, is a dark Brown, or something like unto this. In the rest can be seen all the diversity of Colours with which Nature variegates and beautifies herself; as caused by different earths (or by their Exhalations, as Theophrastus would have it) or by differences in the heats which they have suffered, as Aristotle feels: both truthful opinions.

When under the surface of the Earth, which has not her proper and natural Colour, one finds Ores, it is a certain indication that their exhalations have caused the change in the colours of the surface; and if the exhalations are lacking, solely to heat should be attributed the changes in colour. In addition to the colours caused by the exhalations of the Earths, there is often an added Shine and at times almost a Brilliance: only those Ores which have been heated are dark, rusty, or black. It is a justified Conjecture, from that which has been said, that even at a distance one may recognize deposits of ore by the Colours to be seen upon the hills. This is a thing seen and experienced in the most famous camps of this kingdom, where among the barren hills those that bear ore are noticeable by their difference in colouring.





 ${\it Photo} \ by \ {\it F.} \ {\it D.} \ {\it Aller.}$  Machinery Used in Potosí Mint.







#### CHAPTER TWO

## THE SMELLS OF THE EARTHS, AND CAUSES FOR THE DIFFERENCES

The variety of the Smells to be found among the earths (it is not to be less noted) is another of the admirable phenomena of Nature. Common Earth smells strongly, after the heat of the East Winds, when it receives the touch of the first Rains. Though the heat of the dry Season may have cooked out the moderate humidity of the Earth (and this humidity is necessary to the good smell of all things that may have odour), let it but be mixed with the first Water and it will exhale a Smell that we have all noticed. In some Muds also, such as that of Entremoz in Portugal, and in that of Natá, in Panama, is to be found this Property; and even in these distant regions the Odour is named and esteemed. In Malacca, that famous city of Oriental India (so they say) there is a kind of very odoriferous Mud from which they make ordinary Cups, but these, because of their abundance, have no great Value.

In mines also there have been such manifestations, apart from the ordinary Odours experienced. Henry, Prince of Saxony, being once in Marienburg, as cited by Agricola, found such a pleasant Smell coming from the mine called San Sebastian that he exclaimed in admiration that it seemed to him to proceed from Civet, that land of India so famous for its Perfumes and wondrous products, and which many to-day (and they of no little Authority) judge to be the very place which God created and has as His earthly Paradise. Noticeable also is the Odour given off by *Pacos* (Oxides), if other Half-minerals (semi-oxidized) do not

accompany and neutralize them; and this good Smell is not to be neglected as a favourable sign of the richness of the stones or earths called *Llampos* (Fines): this is an ordinary occurrence in the veins which give Carbonates of Lead. And it is thus that among Miners they test the unknown

Ore, not alone by Sight, but by Smell as well.

The greater part of the other Ores smell badly, either by reason of their natural Decomposition, or because they are mixed with Sulphur, Copperas, or other Salts, a condition not at all uncommon. Some one has thought, in addition to this, that also in the bowels of the Earth there are Things most abominable and evil-smelling, like unto the dung of animals. The certainty is that there are earths and places which instantly kill by their pestilential Odour. And, leaving aside ancient and modern examples, I shall cite two cases where I was present: The rich District of San Cristobal de Los Lipes, being recently discovered, I departed thither. At that time, in a high and beautiful Hill, which with other Slopes surrounded the site of the Miners' camp, two Gallego Miners discovered a Vein which at the beginning they called, and ever since have called, the "Evil-smelling," on account of its effects. They commenced to take out very rich Ore, mixed with white Earth; but at a little depth they were forced to give over their Work, by the bad Smell; which at the same time caused the Death of some Indians among those there working. The Mine was left to itself for more than four or five Years. At the end of this time, I myself being present, another Miner essayed to resume the Work, being tempted thereto by the Richness of the Ore, and the belief that in so much Time the evil odour would have dissipated and passed off; but the trial cost him the Lives of two Indians, who died instantly, and the mine has remained abandoned to this Day.

However, I did not marvel so much at this as at what I saw in another cut in the same Hill, some distance away. In this they were scarcely able to sink a *Vara* before the work



was stopped by the evil Smell which came out of the Earth. Passing by that place some days later, I beheld in the shallow shaft many dead Birds and other wild Animals, killed by the Odour proceeding therefrom. On the other side of this forbidden Hill (reserved for the time that the Divine Providence may deem fit), alongside of a Marsh, there were constructed some houses and an Arrastra for treating Silver Ores. Whatsoever part of this ground was opened, even for the shallowest Foundation, gave forth the evil Odour aforesaid. It was like unto that of a cellar full of Must when it is boiling; dangerous and heavy; and, even to him who is enjoying the free Air it is offensive.

As to the mining District of Berenguela de Pacajes, famous for having Crown-granted Indians for the working of the Mines (even before Potosí), the richness of its Ores would have made it inferior to none, had it not been for the interference of Water in the veins at shallow depths. In the hill which is called Santa Juana, a Miner was carrying on a working very rich and abundant in Silver. Desiring to open up new ground, he drilled a hole in one of the walls, hoping to find another vein: this is an ordinary Task for those who follow mining. He then placed two Indians in that place which seemed best to him; but when with a few blows they had broken into a hollow place, there proceeded thence such a pestilential Odour that instantly the two Indians died. Others who were at a distance having hurried out to advise the Master, he in turn entered to ascertain what had happened and to succour them; but long before he reached them he himself was stricken Dead, and his body remained crosswise on the ladder by which they descended into the mine. And there his Body remained, even up to my time, because there was none so brave that he ventured to remove it to give Sepulture.

In another tunnel of the same Hill there was discovered, when I was in the mine, a small Hole in the lowest of the workings, from which came out with a terrifying noise an exhalation or Vapour so penetrating and heavy as to deprive



of Life him who would stop there. It would extinguish the lighted Candle, when placed near it: a certain sign of the Evil I have mentioned, and one which all experienced and careful Miners recognize. It should be heeded by All.

#### CHAPTER THREE

THE RECOGNITION OF THE EARTHS BY THEIR TASTE

He who follows the art of treating Ores will omit no investigation which may enlarge his Knowledge; and the Sense of Taste does not give less information in determining the Purity or mixture of earths than the Sense of Smell. Pure Earth has no taste whatsoever, while ordinarily that which has a taste owes the same to a mixture with mineral Substances. Scarcely any are free from this quality when they are dry. The foundation of a sweet, or good Taste is Moisture; and, as the earth which has this requisite is also much disposed toward the taste of metallic substances, the curious Miner will not fail to make his tests, following the sure and certain principle that Gold and Silver also occur in the form of Llampos (Earthly fines), as well as in Stones or Chunks, as the Miners of this Kingdom put it. The Earths easily impart their taste to pure Water, if they are placed together in a cup, and more so if there is added the heat of Fire, through boiling once or twice; thereafter one may judge the taste of the mixture or Salt which the cup contains. And he who would care to carry this experiment farther can divide the Solution and remove the visible and solid Part, as will be treated farther on in the part dealing with the preparation of Ores as a preliminary to their treatment.



#### CHAPTER FOUR

#### THE NAMES AND USES OF SOME OF THE EARTHS

Famous in the books of Medicine are some of the extracts of Earths, on account of the effects they have on the Human Body; and it is not inappropriate that the Miner should have some kind of knowledge of them, in order that, if they or their Like are found, he may be able to recognize

them, and to advertise their Presence.

Highly coloured is the earth Lemnia, so called from the Island of Lemnos, where it is obtained; it is very similar in appearance to Almagre (Red Ochre). The difference lies in that Almagre at once stains the hand if touched, while the earth of Lemnos does not. It is sold at its weight in Gold, and this price is due to the Esteem in which it is held and the common belief that it is very rare in the World. Furthermore, because of Superstition, it is mined only one day in the Year, the sixth day of August, as they believe that only what has been mined on that day is possessed of Virtue. It is an admirable antidote against whatsoever kind of Poison or Pest. That which is commonly called Bolarmenico (Armenian Bole) because it is thought to be brought from Armenia, is similar to the aforesaid Earth of Lemnos. Its colour varies from Red to Yellow, and one finds it of good quality and in grand abundance in the mining districts of this Kingdom, particularly the rich Cerro de Potosi, and in the hills of Oruro. It is used as an astringent remedy and for stopping the flow of Blood. To many this common "Bol" has the properties of the "Rubrica Sinoptica" of Dioscorides, the Bolarmeno oriental, and the true Earth of Lemnos.

The earth of Erithria is of two kinds, the one exceeding

white, and the other the colour of Ash; the latter is the better. It is recognized by the violet stain it leaves when rubbed on clean Copper. It possesses astringent and cooling Powers, and it closes fresh Wounds.

White and light is the earth of Samos, and if touched by the Tongue it sticks; it is also soluble and easily broken. Another variety is like unto Stone and is called *Aster*. Both possess the virtues of the earth of Erithria, and, taken in water, they defend against Poisons, and bites of Serpents.

The earth called *Chia* is white, inclined to be ash-like, and is like unto that of Samos. Among its qualities is that of removing Wrinkles from the Face, and imparting a good Colour and Radiance thereto.

The white Selinucia has the same effect, and is the better in that it imparts more Radiance. It is also friable, and

promptly falls apart when thrown into water.

The white *Cimolia* earth, of the sort that is naturally greasy and feels cold to the Touch, is the best, though there is also a sort that is inclined to a purple Colour. It dissolves Tumours, small swellings of one sort or the other, and prevents the raising of Blisters from the burns of Fire.

The earth *Phigite* is very like in colour to the earth of Erithria, but it is found in large pieces, and cools the hand when touched. It sticks strongly to the Tongue, and has the same virtues as the earth *Cimolia*. In its ash-like colour it much resembles the earths of Melos and Erithria. It is rough to the Touch, and in the fingers gives forth a sound like unto that of Pumice stone. It has the virtue of an Alum, though slightly, as recognized by the Taste. Because it cleans the Tongue while purifying the body it leaves a good colour and cures the Rash.

The best of the Earths which are called *Ampelites* is the black, which, if ground and mixed with Oil, easily falls apart. It has the virtue of cooling and dissolving, and is also used for dyeing the Hair. It is wholly bituminous, like *Azabache* 

(Jet).

Of another earth Cardano makes mention indirectly;



this, following the Ancients, he calls *Britannico*, on account of the place from whence it was obtained. It was brought forth from very deep holes. In colour it was white, and, when the Silver thereof was removed, they took that which remained and manured the Fields; which thereafter continued fertile a hundred Years.

A like effect is had from an Earth obtained on some islands in our Southern Sea, not far from the port of the City of Arica. This earth is called Guano, which signifies Manure, not for that it is the dung of Birds (as many have thought), but for its admirable Virtues in quickening that which is sown. It is light and spongy and has a heavy Odour; that which comes from the Island of Iquique is of a dark brown Colour, very like unto that of ground Tobacco, although that which comes from small Islands near Arica is whitish, inclining to Yellow. It at once discolours the water into which it is thrown, as though it were the strongest of lyes. The qualities and Virtues of this and many other marvellous substances of this New World will afford ample room for philosophic discourses when the bright Minds, now occupied in the tasks of taking out and enjoying the incomparable Riches of this Land, occupy themselves in the study of the true Sciences.



#### CHAPTER FIVE

#### THE SALTS, AND, FIRSTLY, ALUM

The mixtures which Nature forms in the bowels of the Earth either can be melted or cannot be melted. If they cannot be melted, and are hard, they are called Stones; if they are soft, and can easily be reduced to very small particles, they are called Earths; if upon melting they return to their original form and Hardness so that they can be forged with the hammer, then they are Metals; and if they have not the hardness and qualifications mentioned, then they are the substances called Salts. There result, from the mixture of the first four kinds, other Compounds, which he who well knows how to count them will find to be Eleven in number and no more. The salts whose moisture has been set by the cold, will melt with the heat, as does Sulphur; but those which have been hardened by heat will dissolve with cold and water, as Alum, Copperas, Salt and Others; of all some brief notice will be taken.

Various are the kinds of Alums mentioned by those who treat of Medicines only; but the true Salt of which we are treating is that called Rock Alum. It is found white and transparent, like unto Glass, also inclining unto a reddish Colour, and it is this latter which is the strongest. the valuable virtue of an astringent, and it is for that reason that the Greeks called it Estipteria. According to the doctrine of Galen, as found in the Fourth Book on the Properties of Remedies, it must be cooling [To the mouth.—Translators] because all astringents are such. And as having this property in the Second Degree, Rupercisa designates it it to be used in the Fifth Essence of Raymond. Many others agree with Dioscorides in that it is very heating; this, how-

ever, is not the place to examine their reasons.

That which is called Alum of Escayola is not a salt, but the earth Samia, which was called Aster by the Ancients. The Seysile or Feather Alum, sold as such in the Chemists' Shops, is not a salt, but a Stone called Asbestos. It is neither astringent to the taste, nor does it melt in the fire, even when kept there for much time: this latter is a particular Property of Asbestos.

The Catino alum is made from the ashes of the herb Anthide, or Sosa, called by us the Glass Plant (Glasswort), of which there is great abundance on the Pampas or Plains of Oruro, and in some parts of the banks of the Langacollo.

Argols alum is that salt which is had when Argols and the Lees of Wine are calcined unto whiteness.

All our Provinces abound in Alum, as in other Minerals. In that of Lipes, near Colcha, the principal Village, I found a vein of Alum, and another I saw near the Hot Springs, hard by La Ventilla, on the road from Oruro to Chayanta. And in this was the true Seysile or Feather Alum, having all the Properties which Dioscorides has set down; which same Alum is brought to Potosí from a district near Porco. It is also to be found in many other parts, and great Abundance thereof could be collected in this Imperial Village, if the waters of the Ravine, or Guaco de Santiago (which are charged with Alum) were put to use.



#### CHAPTER SIX

#### COPPERAS

Caparrosa (Copperas) is a mineral substance very like unto Alum; and these two are frequently found together. The manner of separating them is this: After the mixed Efflorescences have been set free from the Stones and Earths in which they are found, they are boiled with a quantity of urine, and it is thus that they are separated, the Copperas remaining below, and the Alum on top. To the Taste it is biting, sharp, and astringent, and many for these reasons attribute to it the properties of Sulphur, of Iron and of Copper, the efficacy of Alum, the sharpness of Saltpetre, and the dryness of Salt. Some Alchemists have proclaimed the theory that this Substance in itself hides the mysteries of the Philosopher's Stone. Its Latin name, Vitriolum, they interpret thus, forming words, each of which has, as its beginning, one of the letters thereof: Visitabis, Interiora, Terrae, Rectificando, Inveniens, Occultum, Lapidem, Veram, Medicinam. Raymond says that it is frequently found associated with Gold, and that both have a common origin and beginning. This possibly has been the source of the affirmation of many that where Copperas is found there is found also Gold; with which belief Experience in many of these Provinces does not agree.

Ordinarily it accompanies Copper, and is frequently found in abundance with oxide Ores, giving to them the evil Odour of their workings. Those substances called *Copaquiras* are pure Crystals of Copperas; the purest (and that of greatest effect) is that which is called *Piedra Lipes* (Copper Sulphate), from the Province in which it is found. In Atacama also, only a few years ago, an abundance thereof

was found in a mine; that of Atacama being very Green, while that of Lipes was very Blue. There are likewise exceeding White Vitriols as well as the Yellow from which Ink is made. On account of the variety in colours different names have been given to Copperas: as Misi, Sori, Calchitis and Melanteria. (See Pliny and Encelius.) With respect to its various qualities, there are not lacking those who have the same doubts as in the case of Alumbre (Alum) and who, not content with giving it the Third Degree of Heat, would like to assign it to the Fourth Degree. Others, on the contrary, like Juanes de Rupercisa, who probably followed Raymond, place it as being cold in the Third Degree. Its effect is admirable when used to make Agua Fuerte (Nitric acid), in which, as if they were salt, the metals are dissolved and turned to Water.

In this circumstance there is visible proof that one Metal may be transmuted to another, namely, that if Copperas be dissolved in water, it will at once, without further Artifice, turn into fine Copper not only Iron, but Lead and Tin as well. And even Silver may be stripped of its fineness and reduced to Copper, by a little aid from another very common Metal. There may also be obtained from Copperas, through violent heat, the Oil of Vitriol, of marvellous Virtues. There are also made by artifice two kinds of Vitriols, the Blue and the Green, by roasting Copper and Iron with Sulphur. How this comes about will be set down hereafter, and there will be shown the damages this has caused in the treatment of Ores, although up to this Present the reason has remained

unknown.



#### CHAPTER SEVEN

#### SALT

Equally well known and needed in the World is Salt. Rock Salt has the same Virtues as that which is crystallized out from the salt water of the Sea, from Lakes or from Springs; but there is this difference: that the substance of the Salt that comes from the mine is more dense and compacted, and for this reason it is not so easily dissolved in water as that which is crystallized from the Sea. There is an exceeding abundance of Salt in all these Provinces, as well as of Ores. And not among the lesser marvels of this New World is that piece of solid Sea, or crystalline Salt, to be found in the Province of Lipes, as well as the salt fields called Garci-Mendoza. This name of Solid Sea I have given to it by reason of its size, seeing that at its least width it measures sixteen leagues, while it is forty leagues or more in length. At times there have been found holes of the most profound Depth, such that they could not be sounded, and therein have been seen enormous creatures most like unto fishes. A man passes over this region with great risk, as he is blinded by the glare of the Sun's rays reflected from this crystal Plain, unless he has taken thought to shield his eves with a black veil; there is also risk to Life, because it has come to pass that Traveller and Mount have sunk therein, not leaving behind a single sign.

Four leagues from the mines of San Cristobal de Achecolla, in the Provinces of Lipes, there is a small Lake that lies on the top of a low Hill, in the place which is called Tumaquifa. In the centre of this Lake the water boils, now gently, and again most violently and with a most tremendous noise. Curiosity has taken me to see it, and truly indeed does the perpetual Movement and Tumult instil fright; and few are those who dare to venture to its edge. It is so turbid that it seems to be more Mud than water. It has a small outlet, and that which issues therefrom is converted into Salt in the ravine, or *Quebrada*, as it flows along. This is the strongest kind of Salt, showing twice the effect of common Salt in the treatment of Ores, and by trial it has been found to be a very efficacious remedy for Dysentery. It may be that it has some mixture of red Alum to which it owes its vivid colouring. There passes alongside of this Lake a vein of *Judayca* stone (*Lapis Judaicus*) and in the

vicinity there is much Copper Ore.

At a distance of a league and a half from Yulloma, in the Province of Pacajes, there are many Springs of water so salty that, without being evaporated, they crystallize out into the whitest of Salt, and this Salt increases all the Year, and is not diminished nor robbed by the rains of Winter. Close to Caquingora, which is a village of the same Province. there are other salt Springs like to these, as well as in many other parts of this Kingdom. The Salt from mines (Rock Salt), which they call Gemna, or Stone Salt, looking like a true Crystal if it be massive and transparent, is had in lesser abundance in these Parts, though Yulloma has many veins of it. In Curaguara de Carangas the Indians of the region have for many years been mining the Salt and bringing it to these parts, and, a few years back, other veins were discovered on the banks of the Langacollo. But the salt mines of Yocalla, which God has placed so close to this rich Hill and Village of Potosí (so that nothing might be lacking for the treatment of its Ores), have yielded, and still do yield so abundantly that it almost seems incredible. Each day there is consumed at least a thousand and five hundred Ouintales (seventy-five tons), and this rate has prevailed for many Years.

In addition to those uses and effects of Salt which are known to all, Arnoldo de Villanova, in his treatise on the conservation of Youth, says that superior to all Medicines



for this desired conservation is Sal Gemna, or Rock Salt. He calls it Mineral Elixir, and specifies that it should be prepared with substances which will not nullify or destroy its natural Properties; but he does not say what these substances are, nor how they shall be used. Jean Béguin, in his Tirocinio Chimico (Elements of Chemistry, Paris, 1608), shows how to obtain an Oil therefrom, to which he attributes powerful Virtues, saving, furthermore, that he who will bathe himself in this Liquor will remain safe against corruption for many Centuries. And with this Liquor, too, he believes the body of that beautiful Maiden was conserved. to whom Rafael Valaterrano refers, the same having been found in the time of Pope Alexander the Sixth, in a most ancient Sepulchre, as fresh as though she had that moment died, although, as her Epitaph bore witness, she had been interred more than a thousand and five hundred Years.

# CHAPTER EIGHT

# SAL AMMONIAC, AND OTHER SALTS

Among the Salts that are produced without Artifice by Nature, the most rare, and the greatest in virtue and power, is that which is called Almojatre, or Sal Ammoniac. Armoniaco it is vulgarly called, and this name has served to create the belief that it comes from Armenia. I, however, shall call it naught but Ammoniaco, which is the same as Fine Salt (or Ammos in the Greek language). It is found crystallized in pieces under Salt, and from the continued heat of the Sun it is concentrated in such a manner that it becomes the most bitter of all Salts. It is used more among Silversmiths than among men of Medicine. It is one of the four substances called Spirits, because with the heat of fire all its substances can be driven off as smoke, even as the substance of Quicksilver, Sulphur, and Saltpetre. It has the particular Property of cleaning Gold and giving Colour thereto, and it likewise enters into the composition of the Agua Fuerte (Acid) which dissolves Gold.

We have but little knowledge of the true Nitre, which in ancient times was crystallized from the waters of the Nile, although Albertus Magnus says that in Goslar there was a hill abounding in Copper, from whose foot flowed forth a water that dried up as Nitre. Neither have we knowledge of Alfro Nitre, which we might consider to be the froth of Nitre.

Chrysocolla, which is called Atincar, or Borax, is a kind of artificial Nitre. It is made by exposing urine to the Sun, in a copper mortar, until it becomes thick, and crystallizes. Others, however, compound this Salt from Almojatre (Sal Ammoniac) and Alumbre (Alum).

Nitre is bitterer than Salt, but less salty, and lying

between the two is Saltpetre. This is composed of very fine and dry particles, and is begotten in the foundations of old Houses, and in parts where Cattle may be driven together and shut up. It grows in the Earth from whence it once has been removed, if the Earth be piled up and watched. Furthermore, if heaps of ordinary Earth are sprinkled with Saltpetre-bearing water, they will in time yield bountifully, increasing like unto seed which has been sown. Well known is the use of Saltpetre in the compounding of Gunpowder and Aguas Fuertes (Acids), and it is also of use in the melting of Metals, as will be set down hereafter.

### CHAPTER NINE

## OTHER SALTS CALLED BETUNES (PITCHES)

One of those things that work most harm to Metals, especially in smelting, is Pitch, which, if it be not removed before they are put into the strong Fire, burns them, and turns them to Slag. There are twelve sorts of pitch. although there are very few that are found mixed with ores. These twelve are Asphalt, Soft Bitumen, Petroleum, Soft Pitch, Hard Pitch, Bituminous Earth, Fossil Tar, Anthracite, Soft Coal, Amber, which is called "De cuentas," (Bead Amber), Odoriferous Amber, and Camphor. these Pitches are the unction or grease of the Earth, although there are some who believe that Camphor is the gum or tear of a Tree, called Capar, growing in the Island of Zanzibar. And it is also thought that Amber, or Succino, is obtained from another herb like unto Pennyroyal, with which it is commonly found growing. The odorous Amber is begotten in the Sea, by a great Fish of the Whale kind. From the similarity that may be found in these, it is not repugnant to thought that other substances may sweat out of the Earth, and become Pitches, as it was said before.

Asphalt is collected in the Lake of Sodom, or Dead Sea of Judea, into which flows the River Jordan, three leagues from the city of Jericho. It is nothing more than a certain kind of Grease which floats on the surface of that Lake, and, being carried by the wind and waves to the beach, becomes compacted and hardened. It is like unto lampblack, but harder and of a better Colour. Before God chastised the wicked cities of Sodom, Gomorra, Admah and Zeboim, there abounded in that most fertile valley wells of this Pitch (so says the Sacred History, in the Fourteenth

Chapter of Genesis). It is also found in many other parts and Provinces, and in some parts it is used in place of oil for the lamps. In this Kingdom it has never yet been used; and moreover, all being occupied in the search for the wealth of Silver and Gold, but little attention has been paid to this and many other Curiosities. Nevertheless, an abundance of pitch-bearing materials exists in the Cordillera of Chiriguanes, on the frontier of Lemina. There is but little communication with this Place, because it is among the war-like Indians.

Lacking the true Asphalt, one may satisfy himself with the Pis-asphalt, which is a natural mixture of Asphalt and Rosin, as is indicated by its Odour. Naphtha is a white, luminous liquid, though sometimes found black in colour. This latter is called Oleo Petroleo (Petroleum Oil), and is of admirable Virtue in curing chronic Aches brought on by exposure to cold. Naphtha attracts unto itself Fire, even as the Magnetic Stone attracts unto itself Iron, and this with such Force that even when distant from the Fire it will burst into Flames. This is confirmed by the lamentable Incident seen by Count Hercules Ferrariense. The Count had sent a Workman into his field to make straight a shaft. from whence there flowed, together with Water, a considerable abundance of Petroleum, because there were crevices in the shaft, so that much was lost. Now, when the Workman had asked that a light be let down to him, that he might the better see what he did, and they had let down a lantern, through the small openings thereof there was attracted Naphtha unto the Flame, and straightway the whole shaft was afire. With all Violence (as it had been a Piece of Artillery) the shaft spewed out the poor Workman and broke him into pieces, while at the same time it swept away the shelter of Branches that had been constructed over the shaft. And the Count himself told this tale to Matiolo, who in turn makes mention of it in his Dioscorides.

In the fire Asphalt and Pis-asphalt melt like Wax or Rosin, and in this they differ from Anthracites and other



mine coals, which burn and are consumed like Pine, or other firewood. Up to this present I have been unable to get further News of these and other Pitches, whether they exist in these Provinces; but I am persuaded that it is not so much that they are lacking as that they have not been observed and recognized.



# CHAPTER TEN

#### SULPHUR AND ANTIMONY

Sulphur is a Mineral extremely well known, begotten as an unctuous substance and inflammable in such a measure that it among all the Elements is held to be most like unto Fire. It is called Masculine Seed (by those who write of the secret Philosophy of the Metals) and the chief aid of Nature in Creation. It is said that the difference between the various kinds is due to Stages of purification, and to mixture with Quicksilver. And already it has happened that the keeper of a Drug Shop, wishing to prepare Cinnabar (which is compounded from these two Minerals alone) found that by accident they were converted into a sheet of the finest Silver. Theophrastus never ceases (though with many exaggerations) to laud the Marvels of Sulphur; and he claims that it is by a special Providence of God that the mysterious attributes thereof are unknown to the Public, while at the same time it is the confusion of those who, while claiming to be Philosophers, deny the Transmutation of Metals. He himself prepares and demonstrates the use of a kind of Oil which he calls Epatica Sulfuris and with which Silver is converted into Gold. Furthermore, the Author of the Hellenic Discourse tells what things are necessary to prove this possible, on a small scale, with the aid of Crude Sulphur, by the smoke of which Quicksilver may be solidified and converted into Silver; and to this there are many Eyewitnesses in this Province. From this same Substance, distilled in a glass Bell, may be obtained a most powerful Oil, admirable in its virtues: among many others is that it is able to drive out the effects of venereal disease when taken in any convenient Drink at the rate of

three or four drops per Day for the period of one Week. It is good in cases of difficult urination, for the pains of Gout, and for other Sicknesses, as may be seen in the works of Diodoro Heuchiente and many Others. There is a great abundance of Sulphur in the Province of Los Lipes, and in the confines of Pacajes in the very high Mountains of Tacora, or Heights of Arica. Also in many other places where it is found associated with Ores of the rich mining districts of this Kingdom.

Antimony, or Estibium, which some Miners know under the name of Alcohol, and others, particularly in Oruro, called Mazacote, is a mineral very similar to Soroche, the very shiny and easily broken mineral of Lead (Galena). It is also found fibrous, sometimes whitish, and fine of Grain, as Steel when it is broken. It is composed of indefinite and poorly mixed proportions of Quicksilver and Sulphur, seeming to be an abortion of Nature, which, though it should have been a Metal, remained but the uncertain mixture aforesaid. By Artifice there is obtained from it a sort of Ouicksilver called Regulus, somewhat like unto Lead, but not of so lively a Movement as the Quicksilver. Porta, Veguino and others have shown the method. Also, the Sulphur thereof may be separated out with Agua Fuerte (Nitric Acid); having then its proper greenish Colour, and burning after the manner of common Sulphur. Basil Valentine in his "Triumphal Car of Antimony," among the many other excellent Virtues that he claims for Antimony, shows how from it may be made that which he calls Fire Stone, with which he converts the other metals into Gold. Paracelsus also wrote not a little to the same effect, and other Alchemists constantly speak of an Oil to be had from Antimony, which will effect this same Transmutation. But it is with much more Authority, and the necessary Experience, that Maricio praises his own preparation of Antimony for curing old Ulcers and other evils needing Medicines. Antimony possesses virtues as a dryer and astringent. The preparation called Hyacinth (Tartar Emetic) possesses most



powerful properties as a purgative and a producer of vomiting. Ordinarily Antimony is brought forth from the Mine mixed with the ores of Silver, and especially with those called *Negrillos* (Black Ores), in all this Kingdom; although in many parts it is begotten and found pure. It causes much damage (in the treatment of ores) as do Pitch and Sulphur; whence arises the necessity to remove it, as will be explained hereafter.

#### CHAPTER ELEVEN

## PYRITE, ORPIMENT AND DRAGON'S BLOOD

Margarita (Pyrite) is the same as the Fire Stone; it is thus called because though there may be others that give off fire when struck with Iron, none do so with such an abundance of Sparks as this Mineral. Some would have it that it is begotten by undigested Vapours; others say that it is composed of a very impure Sulphur, or of Pitch, and Stone. It is begotten in all kinds of Mines, and especially those of Copper, and black ores of Silver, and it was probably on account of this that Dioscorides said Margarita was a kind of Copper Mineral. Although Albertus and others considered that it was sterile, and in itself contained no Metal, experience has shown the contrary; for at Monserrate, Las Chichas (where there are many Mines), when they commenced work on the veins, as much Silver ore was found in the veins as there was Pyrite. In this Hill of Potosí, and others, there is a kind of Pyrite, very fine of Grain, which is a sure sign of richness when found among the black Silver ores. There are as many sorts of Pyrite as there are Ores, and these correspond to as many Colours, the most common being of a golden Colour. They smell of Sulphur when burned, and many give forth flames: proof of that composition which was herein set down. Occasionally Gold, Silver and Copper are found in Pyrite. Pyrite is damaging to the ores it accompanies, flouring Quicksilver, and fouling Furnaces, as will be mentioned hereafter, when at the same time the remedy will be mentioned.

Oropimento (Orpiment) and Sandaraca (Dragon's Blood) are of the same Nature, have the same Qualities, and differ only in the greater or lesser degree of cooking they may

have suffered in the bowels of the Earth. And it is thus that we may say that Sandaraca is nothing more than Oropimento which has been further cooked, and for the same reason is more subtile in its Effects. He who would prove to himself the truth of this, let him place Oropimento on lighted Coals in a clay crucible; and the same after it has cooked will be of a deep Red, of a Colour equal in vividness to the most perfect natural Sandaraca. Wheresoever men find Orpiment, it is a certain sign of Gold, and it may even be a breeder of this precious Metal. Pliny mentions that in the time of the Emperor Caligula some Gold was obtained from Orpiment, but since that time no one has essayed to do this, by reason of the Cost exceeding the Gain. The best Orpiment is that which has the shine of Gold, is in thin Flakes, and is easily broken down into pieces like Scales. The most perfect Sandaraca is that which is the reddest; it should be pure and easily broken, of the Colour of Cinnabar, giving off by itself a heavy odour of Sulphur. It differs in this (and much more in its medicinal Qualities and Virtues) from Sandix (Red Lead) of the same colour, made from Albayalde (White Lead). They (Orpiment and Dragon's Blood) are Poisons, not only for the human Body but for Ores as well, on account of the force with which they flow and consume; in this they are like unto Antimony, Sulphur, and other dry Salts. On account of the considerable ease with which they burn, when mixed with Ores, they consume the Moisture of them, and leave them no longer amenable to treatment.

There are other Salts, rarer and less known, such as that said to have been found in a mine of Augsburg, white and hard, which was poisonous to the Animals that tasted of it. Possibly it was a vein of this same kind of Salt which I have heard of through trustworthy Persons as existing in the Province of Conchucos, of the Archbishopric of Lima. They say that the Indians used it to poison whomsoever they had a grudge against, until it was closed by that wise Archbishop of the Crown, Don Toribio Alfonso Mongrovejo.



## CHAPTER TWELVE

#### THE GENESIS OF STONES

There can be no doubt that there is some active Virtue which begets and creates Stones, just as there is for other common and corruptible Things in the Universe; but it is difficult to find out what it is, as there is no particular Place for the genesis of Stones, the elements being found in the Air, in the Clouds, in the Earth, in Water and in the Bodies of Animals. Their principal constituent (according to Avicenna and Albertus), is a mixture of Earth and Water, which, if it has more of Water than of Earth, is called a Salt, and if more of Earth than of Water, is called Mud. Mud from which Stones are made must be viscous and tenacious, like unto that from which they make Bricks, Pots and other Vessels; as, if it were not so, when once the Humidity was consumed, the Matter would not remain united, but would be reduced to powdered Earth. It is also a necessary condition that the Salt (which is to be converted into Stone) be Viscous, as is the case with our own Bodies; for it is a fact well-known among Physicians that Stones are created in the Kidneys and Bladder, out of viscous and tenacious Humours cooked by bodily heat.

Full of this petrifying Sap undoubtedly is the Water so well known in this Realm, which flows near Huancavelica; this is collected in moulds of the desired size and form, and, on being exposed, for a few days, to the Heat of the Sun it crystallizes into Stones of which Houses are built. Animals which drink of this Water die; and it is not difficult to discover the reason.

In the hills called Pacocaba, a league away from the mines of Berenguela de Pacajes, there are some Springs of this Water, which are full of this same Salt; these, as they flow, are condensed into a heavy and hard Stone, of a Whitish colour, tending to Yellow. Furthermore, any porous stuff which may absorb this petrifying Salt is liable to be converted into Stone; and thus there have been seen in various places whole Trees, Parts, and Bones of Animals, changed into a very hard Flint. I saw some pieces of wood in the city of La Plata (found in the great River of that name), of which all the Parts that had been immersed in water were very fine Flint. I have likewise seen the Teeth and Bones of Giants, dug up in Tarija, all converted into a very heavy and hard Stone.

Stones have their varying Forms which distinguish them into different Species. Ignorant of the conditions, we define them by indefinite terms based on their outward appearance and irregularities. The Form of each one is accompanied by its special Virtues, which are much greater than those of Plants and Animals, being in proportion to the greater length of Time occupied by Nature in their generation. As Plants and Animals were destined to have such different Objects and Effects, there could not be given to them such a uniform and well mixed Character as has been given to Stones. To work such a Miracle, the soft Stuff of which they are composed could not be given so much of Strength; while the Hardness of Stone is not adapted to a diversity of Figures, and thus Stones are not found in the shape of Leaves, Flowers or Fruits, Feet or Hands, like unto Plants and Animals; but they are possessed of greater Virtue than all these.



# CHAPTER THIRTEEN

# THE DIFFERENT SORTS OF STONES

All the different Sorts of Stones may be reduced to five If Brilliant and Lustrous, they are called Precious Classes. Those which, on being broken, are converted into Splinters, or Scales, are Flints; if they are rounded, they become Pebbles; and those which are not possessed of the Characteristics mentioned, are converted into large Stones or ordinary Rocks. But Miners give names, which they ordinarily use among themselves, to the Stones on which Metals are deposited, or in which they are created. Quijo (Quartz) they call the stone which ordinarily contains Gold, Silver or other Metal; veins with stone of this nature are of more permanence and are more Solid than others. Cachi (Barite) is a kind of Alabaster, white, crusty and easily broken, the word signifying Salt in the common language of this Realm; and it is called thus because of its resemblance. Paco (Oxide) veins are found in it, carrying much Plomo, which is the name given by Miners to native Silver. Chumpi (Magnetite), called thus on account of its brown Colour, is a stone of the nature of Emery with some Iron. It shines rather darkly; and the treatment thereof is difficult, because it offers Resistance to heat. It is found with Black Sulphide and Ruby-Silver in Potosí, Chocaya and other places.

Lamacradria [?—Translators] is very compact and solid, and on being broken shows neither Grain nor Crevice; the colour thereof varies from light Yellow to dark Red.

Almadaneta (Hammer Rock) is the name given to another stone by reason of its hardness and weight. It is very Solid and of a dark Colour, and when it has become ripe or rotten, precious Metals are created therein, as in the

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case of Quartz. Gold is found with Flint. I have seen in the Provinces pure Copper and Silver Ores in the same rock.

Amoladera (Grindstone—Sandstone) is the ordinary stone which, from the Use to which it is put, is familiar to us all. Therein are found rich veins of native Silver, but more generally Copper ores. Very rare and not lasting are the veins of Silver ore created in Slates, the same being a more common wall for veins of Gold.

Ciques (Rhyolites?) is the name given to other Stones which are begotten with Ores or alongside of them and next to the walls; they are Rough, and not very hard, nor do they usually contain Metal; although, in the case of very rich Ore and Veins, something may be absorbed by the Ciques in their immediate vicinity. Famous have been, and are, the Vilaciques of this very rich Hill of Potosí, on account of the great abundance of Silver which has been drawn from them; and this is not the least proof of its unequalled Prosperity nor the least glory thereof. Vila, in the language of the Natives of this Province, signifies Blood or something Red; and it is on account of the streaks or small spots of this colour in the Rocks that they are called Vilaciques.

## CHAPTER FOURTEEN

#### PRECIOUS STONES

Precious stones are Transparent (as the Diamond), Opaque (as the Onyx), or partake of the Nature of both (as Sardonyx and Jasper). Water is the principal Cause of the Transparency, as Earth is of the Opacity; and thus some Stones are more Lustrous and Transparent than others, on account of the Fluids out of which they were Coagulated, some being purer and clearer than others. White Stones, therefore, originate in fluid like unto Water; and thus they are more diaphanous and clear, as the Crystal and Iris (Rainbow Stone). The Diamond is engendered from a less clear Fluid and is therefore darker than Crystal or Iris. The same variation is noticed in all the other Precious Stones, of whatsoever Colour they may be, whether begotten of Green fluids, like the Emerald or dark green Agate, or of Blue fluids, like the Sapphire, Cyanite and certain species of Jaspers; or Red fluids like the Ruby; or Purple fluids like the Hyacinths and Amethysts; or Golden-coloured fluids like the Chrysolites and Topazes; or mixed, like Opals.

And thus it may be rightly understood that the remaining Stones, which are not Transparent, are made up of a Mixture of Fluids, black and impure, even as we have seen that Water, although it may be very Clean and Clear, loses its transparency if mixed with a little Ink or other similar Liquid, but does not lose the Lustre of its Surface. To the Fluids mentioned is due the difference of colour of various mixtures from the extremes of White to Black, in the substance of the Stones. Nevertheless, Raymond, the authority of many, attributes this diversity of Colour more immediately to the Liquors and Juices filling the cavities of Ore;

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which Liquors and Juices, being filtered through very hard Rock, are coagulated as Precious Stones, valued and esteemed in proportion to their Origin. Thus, to Gold would correspond the Ruby; to Silver the Diamond; to Copper the Emerald; and in like manner all the Others. In the "Compendium of Transmutation" which he dedicated to Robert, King of England, Raymond expressly teaches how to make Artificial Precious Stones, as fine and of as good Properties as Nature compounds them, out of the different Mixtures of metallic Waters; this knowledge, surpassing the other Achievements of that Admirable man, would appear to be beyond the power of Humanity. The foregoing, however, is supported by the fabrication of different coloured Enamels, the Colours of which depend upon the Mineral Substances with which the Glass is melted and mixed: artificial Stones are made in the same way.

Flaws are found in transparent Precious Stones; which, for the very Reason that they are Transparent, make the Flaws to be the more readily seen, like Spots on Fabrics of the richest Silk and Cloth; and few are those which have no Flaw or Defect, such as a Hair, Cloud, Shadow, Salt or other substance engendered in them, on account of the Fluid out of which they were made not having been all of one Colour. The shadow had its origin in that part of the fluid which was Darker; the cloud in that part of the Fluid which was Whiter. The Hairs which deface Precious Stones (and chiefly the Sapphire), the Opaqueness which clouds especially the Opal, and the Dullness which clouds the Emerald, are defects of Genesis due to Fluids which have not the true and proper Colours of the Stones in which they are found.

FUNDACIÓN JUANELO TURRIANO

## CHAPTER FIFTEEN

#### WHETHER THERE BE PRECIOUS STONES IN THIS REALM

Silver alone has been the principal Object sought by those who so far have resided in this Province; and thus there has been no Search for Precious Stones wherewith to adorn the Crown of its Natural Wealth; however, there are no small indications that the same are not wanting in this very prosperous Realm. There are constant reports (and I have heard them many times in the Province of Los Lipes), that in the Province of Atacama, its neighbour, there were very fine Diamonds; and that for a little Coca, not worth two Reales (one-quarter of a Peso) an old Indian woman had given a Handful of uncut Diamonds, which in Spain would have been worth many Ducats. The ground abounds in very Handsome and Brilliant Stones; and the credit given to this Province for its Wealth in this kind will not be without foundation. There are many Amethysts in the Hill of that name, hard by the Esmeruco mines; and in the rich mine of Santa Isabel, of New Potosi, there were brought forth (from its rich Silver ores) perfect Stones of this kind. They exist also towards Paraguay and Buenos Aires, where they have been created in the Pampas or Plains, at some little depth beneath the Surface, on what are called "Cocos" (Coconuts). These are like unto balls, the bigness of a Head, of hard and very heavy flint-like Stone, the shell thereof having the thickness of two fingers, hollow inside, and studded all over with points wonderfully fashioned according to the Nature of these Stones; more or less Hard, depending upon their Condition when they burst. When this happens, there is a noise not less than that made by a Piece of Artillery, the Earth trembles for a considerable

Distance, and Cracks are opened in the Surface. These are signs for those who hear the Explosion to dig, and take out the "Coco" broken in two or three pieces—a well-known and frequent Occurrence in those Parts. On the road from Poton to Los Lipes, near the place which is called Agua Caliente (the name having been given because of the springs of Hot Water) there is a plain covered with Crystalline Stones, pure and transparent, wrought by Nature into the form of Pyramids. I collected a number of these whenever I passed that way, admiring their Beauty; for each one seemed a Sun as it reflected the rays of that orb. The largest one I found was of the Thickness of a Thumb.

An abundance of these stones (but of much smaller size) were found in the towns of Callapa and Yuyama, of the Province of Pacajes. Some also I found cut by Nature in the likeness of Diamond Points, and of the size of Chickpeas; and, having washed away the Sand, I several times saw small Points of the Colour of transparent Gold, like very fine Topazes, and others like Garnets, which, had they been larger would have been very highly Prized. I do not doubt that larger ones would be found if they were

diligently and carefully sought after.

The Stones found in the mine which is called Camara, in the Province of Larecaja, compete in Beauty with Diamonds. In this Realm they are worn in Bracelets and Rings.

In that place which is called the Morro of Arica (Arica Bluff) in the Port of that name, there is a Mine from which transparent Stones like unto diamonds are brought forth. They resemble the Diamond in Hardness, and are also esteemed as Jewels.

Very fine Turquoises are found in Atacama; I saw one in Los Lipes as big as a two *Real* coin (say, a quarter). It greatly pleases the Indians of this Province to make a Show with strings of Stones of this kind, very finely and curiously wrought, the Males wearing the larger Stones as Necklaces. Some of the Stones are green; both sorts are



much liked by the savage Indians called Chiriguanes, and as barter there is no other thing which they esteem so much.

Pearls grow on the Coast of Atacama and Mejillones. After they have been withdrawn from their Shells, they are brought to these Provinces and sold. It is quite a common thing to find them in Shell-fish when these are being washed

for cooking, and they may even be eaten.

As to the Coastal Provinces, I have no definite knowledge; in these Realms they are talked about very little or not at all. Furthermore, my chief intention has been no other than to give Your Lordship an idea of the Minerals in the Provinces subject to your Jurisdiction, which I have personally seen. At the beginning of the Conquest of this Realm, very large and beautiful Emeralds were found among the Indians, as it is set down in History.



# CHAPTER SIXTEEN

### OTHER KINDS OF STONES

An extended Discourse upon Stones would import but little to Miners (and chiefly for their sakes is this Treatise written by order of Your Lordship), as even the more common would fail to be recognized. None the less, if in the workings of the Mines, there should be found a Stone of rare Beauty on account of its Colour and Transparency, it would of itself awaken Admiration and Regard if it were not that the Greed for Gold and Silver blinds the Eye and impedes investigation in such wise that it allows no Notice to be taken of the Stone. But, as reports have been spread at the same time of all the Mineral Substances found here in these Provinces, and Stones which partake of the Nature of Marble are those which, after Precious Stones, are held in highest esteem, it would not be fair to pass by in silence those which we know in this Country, and which, in view of their Abundance and Beauty, not only compete with, but excel the most famous Marbles mentioned in History. Let the first place be given to Atacama, worthy on account of the many wonders of all kinds of Minerals and Precious Stones found in that Province, of being specially studied and carefully examined by Persons of great Experience in these Matters.

The Province produces Stones of all Colours, with such beautiful Hues and Lustre, that it is only on account of the Abundance and Size of the Deposits that they are not looked upon and counted as amongst the most Precious.

The whole Realm is full of curious Altars made of these Stones; and not a few have been transported to Europe. They have not yet been devoted to other uses, either for want of Artificers to work them, or because the desire to return to Spain, rich in the worldly Goods, is common to all of us who live in these Parts, and thus there is no reason for any one to wish to perpetuate his Memory by superb Edifices which could be embellished with these Stones.

At the time that this is written there is a Stone in this Imperial Village worthy, on account of its varied Colours, Lustre, and Size, to be seen by, and placed at the disposal of His Majesty the King, our Master. It is six palms and six fingers long, one palm less wide, and two fingers thick, in the form of a Slab, and very Solid; it is full of very beautiful forms in the likeness of Clouds, caused by the blending of its Colours, among them being Red, both fiery and light, another shade rather darker, Yellow, Green and White. On the darkest part of the Slab it is as though Snow had fallen or Milk been spilt, such is the Whiteness seen among the Shadows.

A league distant from the Mines of Berenguela de Pacajes other Stones are found, not inferior in their high Quality, Substance and Lustre to those of Atacama, although not with such diversity of Colour. They are of the whiteness of Alabaster, and transparent; and that they are more so in some places than others is the cause of something like Clouds in them which embellish them and make them very pleasant to behold. They absorb no Liquid of any kind, and are so solid that they appear to partake of the nature of Crystal. The very large Baptismal Font of the Town of Yulloma is fashioned of a single one of these Stones; and although it is over six fingers thick, the light of a Candle placed in it can be seen from the outside. In the College of the Company of Jesus, in the city of La Paz, there is a beautiful Font and Column of this Stone. The Water running up into the Basin through the Column can be seen from the outside, as though the Column were of transparent and clear Glass.



# CHAPTER SEVENTEEN

SOME IRREGULARITIES IN STONES, AND THE CAUSES THEREOF

In addition to the Brilliancy and Transparency which, as we have shown, exists in some Stones (though not in the most ordinary ones), other Properties may be observed in them, such as the Hardness of some and the Softness of others. Hardness is such a special Property of Precious Stones that those which a file can scratch are not so classed. If the substance of which a stone is composed is Tenacious, and great Heat is required to dry and evaporate the moisture out of it, the same is a cause of its Hardness, because it compresses its Substance, and dries it within itself. If it possesses but little or no Tenacity, and its Humidity is easily evaporated by Heat, while the Earth in it is easily burnt, the stone is Soft and easily broken. Cold, also, since it compresses and condenses the Substance, is the cause of Hardness in Stones which are coagulated by it; and such are those that melt under the action of Heat. which allows the escape of the Humours coagulated within them.

Stones which have not within themselves so much Humidity as will preserve the Earthy Part of which they are composed, burst and fly into Pieces under the action of Heat; those which are exceeding dry are reduced by the action of Heat to Powder or Lime.

Some stones are porous, and others very massive and well kneaded. In the former, the Liquid and Earthy parts are not well mixed; and thus they give up, under the action of Heat, those parts which did not contain enough Earth to defend them from the effects of the Fire. The

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volatile part being driven off, there remain vacant places or Pores, which make the stone spongy; just as from oppo-

site causes the reverse happens with solid stones.

Very often various figures are found in Stones, and this is one of the things in Nature which excites no little Wonder. Whether it is due to the mixture of their Components, the Colours or veins of the Stones, or the cloudlike combinations in them, or not, there are likenesses of Towers, Sheep and other Animals and Figures in them. To Lead which has been melted and dropped into Water the same thing happens. Celebrated among Writers is the Agate of King Pyrrhus which represented Apollo and the Nine Muses as perfectly as they could have been drawn by the most excellent Painter. Cardano had another which was a true portrait of the Emperor Galba. It is said that in Constantinople, in the place which is called the House of Wisdom, there is a kind of Marble Slab of which the veins form an image of St. John the Baptist, with his Shirt of Camel's hair, so exact that nothing would be wanting to make it complete in its delineations, if only one of the feet were more perfect.

When in any kind of stones there are found ordinarily the same signs and figures, the same is not the work of Chance, but rather of special Intention, not without Mystery, by Nature. Such is that referred to, by Leon Bautista, as being found in the country near Verona, in which is a perfect drawing of the seal of Solomon; another black Stone showed the lifelike form of a Serpent. The latter Stone had the property of attracting serpents to it; and the man who presented it to Albertus Magnus asserted that he had seen over five hundred of them piled upon it.

When Stones are found which are like unto Animals or Parts of them, or parts of Plants or other things, not flat as in a Picture, but raised, the cause may be that already given; that is, the petrifying Fluid has been taken into the Pores, and turned into Stone; and this is maintained by Avicenna. But, although such reason may sometimes be accepted, there seems not to be justification for accepting it

without question. On the sides of the Meissen Mountains in Alsace, near to the Lake of the latter name, there are found on the surface of the rocks raised Figures of Frogs and Fish, of pure Copper; and they are as common and lifelike as their origin is unknown. In olden times Conchitas (Little Shells) was the term applied to a kind of Stone which showed form like unto those of the Shell-fish of the Sea. It was thought that these, after the lapse of a long time passed in the company of Stones and the Fluids of which the same were created, had become as Stone; and their existence was used as an Argument to prove that in times past the Sea had bathed the region in which the City of Magara is situated—the only place where the Conchitas were found. To-day, however, there is no room for this way of thinking. A proof of this is the wonderful Vein or kind of grey and iron-stained Stone, in parts Yellow, on the slope into the Oronesta valley, near the road from here to that place. In it are found a wonderful variety of Figures so truly formed that it could have been accomplished only by the Creator of Nature. I have in my keeping Stones in which big, medium-sized and small Shell-fish are shown in the concave parts as well as on convex surfaces, most perfect in their minutest details. This is in solid ground, the most rough and mountainous of the Realm; and it would be lunacy to imagine that the Sea had at any time flooded this Province, and left the Shell-fish in this Vein. There are also Figures in the Rock the Perfection of which is such that it cannot be described; Toads, Butterflies and other more extraordinary Creatures, to which I will not refer at greater length, as I do not wish to scandalize those who may not believe me; but I have heard of these things from Persons worthy of credit. Opposite this mysterious piece of land, on the other side of the Oronesta valley, is the famous Pucara, which in the language of this Province, means Fortress. It is by Nature the most protected place in the World, being at a very high altitude, and seven leagues around, enclosed by most high and inaccessible



Mountains. At one point only is there an entrance, which is a small one at the top of a steep Ascent. In the spacious site above, there are a number of Streams, much Wood, and Pasture, Ravines and land good for the Use of Man.



# CHAPTER EIGHTEEN

#### THE CREATION OF METALS

It is no wonder that, respecting the matter out of which Metals are made, there should be such a variety of opinions among Persons authorized to express them; for it would appear that, by a special Providence, the Author of Nature wished to hide them in the Depth wherein they were created, and in the hard Rocks which enclose them, in order to place some Obstacle to human Ambition. Those who have risen to the rank of Philosopher through the study of Causes, leave on one side the raw material as a very remote Principle of Metals, as it is of all the other corporeal things of the World, and indicate another, also very remote, which is in part, a certain Humid and Unctuous Exhalation, together with a certain portion of viscous and greasy Earth, from the Mixture of which results both Metal and Stones. if dryness predominate in the Mixture, Stone results; and if it has a greater amount of Greasy Water in it, Metal results: this is maintained by Plato, Aristotle and their followers. From the abundance of this pure, shiny Humidity is derived the Lustre of Metals, in which, among the other elements, Water, as is well known, predominates; and thus they flow and melt under the action of Heat. From the varied Temperament and Force of the matter referred to is derived the Diversity of the metals, of which the purest of all, and Nature's chief effort, is Gold.

Many of the generality of People, in order to avoid profound Discussion, say that in the beginning of the World God created Ores in the form in which they to-day exist and are found in their Veins. This is an offence to Nature, denying to her, without any Reason, the productive Virtue she possesses in all other sublunar things. Furthermore, experience in many parts of the World has proved the contrary. As an example and proof of this, it is sufficient to note what is brought to pass before the eyes of all, in Ilua (Elba), an island near Tuscany, where Iron abounds. After the Men have worked the Veins to the greatest possible Depth, they return the Earth and dumps to the workings; within a period of not more than ten or fifteen Years great quantities of Ore are taken out, into which the dumps and Earth have been converted. The same thing, in the opinion of many, happens in this rich Hill of Potosí. Be this as it may be, we all have seen that Stones which years ago were left in the mines because they contained no Silver, having afterwards been taken out, yielded Silver so continuously and abundantly that it can be attributed only to the per-

petual Creation of Silver.

The Alchemists (a hateful name on account of the ignorant Multitude who, with their Lies, have discredited it) with more profound and practical Philosophy, practising the Anatomy of Nature's Compounds, and reducing them to their first Principles, argue thus: The sun (they say) and all the other heavenly Bodies, with their Light, either their own or reflected, travelling continually around the Earth, heat it, while their subtile rays penetrate its Veins. Having been heated thus for a long time, it is converted into another Substance, also Earthy, just as we see Wood and Stones converted into Ashes and Lime. This Earth thus heated, mixed and cooked with Water, is transmuted into another Species, which contains in itself something of the substance of Salt and Alum. Each day we see like effects in lyes of lime or ashes, in sweat and urine, which, through cooking, acquire the taste of Salt. The raw material, or basis of the Generation of Metals, is Vitriol. To believe the foregoing is all the easier when we see that all Metals can be reconverted by artifice into Vitriol. The manner of doing this will be set down hereafter.

This Vitriol, through the action of Subterranean Fire, and



the attraction of Celestial Fire, exhales two fumes or Vapours, one earthy, subtile, unctuous and in some measure assimilative, which the Philosophers call Sulphur, because in its Properties it resembles that Substance; the other humid, watery, viscous and mixed with subtile Earth, which is the immediate substance of Mercury. These two Exhalations find a free and ample escape from the Earth, and, being raised up to the region of the Air, are converted into Comets, Clouds, Snow, Hail, Lightning and other Things which in that Region are created and appear.

If, however, they are in such a small and faraway place that they can find no escape, they seek for it among the Cracks and Fissures of the Rocks, where they thicken and are converted into those things which are called Semiminerals.

If these Fumes penetrate Rocks, and cannot find a certain kind of Sulphur, cleaned and brilliant as Silver, somewhat like unto Pyrite, without which Metals cannot be created, the Rocks are stained with different Colours.

If Stone (of such a Hardness that they cannot penetrate it) prevents the escape of the Fumes, then they are converted into perpetual springs of Water, in the same way as is seen in ordinary Distillation. But if in passing through the Stones, they find Pyrite, or Sulphur that has been cleaned and almost fixed (as already set down in this Work), they decompose it and mix themselves with it, and by successive Cookings they thicken in the mine, harden and become Metal. Bracesco advances this Argument in his comments on the Book of Geber. Most authorities maintain that the primary components of Metals are Mercury and Sulphur, and that the varying proportions in the Mixture, and the greater or lesser Purification and Expulsion of foreign matter give rise to the difference seen in Metals.



# CHAPTER NINETEEN

DEFENDS THE OPINION OF THOSE WHO SAY THAT MERCURY AND SULPHUR ARE COMPONENTS OF METALS

Those who do not judge as feasible anything excepting the Logical (an Assumption which is unworthy of the Wise, and which ought to lower the credit of many who are thought to be Learned) deny to Art the possibility of transmuting Metals, using reasons which not only do not convince, but do not even seem plausible. This is not the place to indicate or examine them; although, in view of their connection with a Knowledge of Metals, it will be necessary to touch upon some of them, and show clearly the Weakness of their Base.

They say that the Alchemists ignore the Manner in which Nature creates and perfects Metals, and that they err in maintaining that Metals are composed of Mercury and Sulphur, because if that were so, there would be signs left of both substances in Gold and Silver mines, as well as mines of other metals; whereas experience has shown the Contrary to be the case:

The first part of this Assertion is of no importance, as it will prove, at the uttermost, that ordinarily those who effect Transmutation proceed mechanically, instead of being guided by Scientific Principles; but this would not take away from the possibility of their being accomplished, or from the fact that they had been accomplished.

In the Second Part of the Assertion is to be seen the manifest Audacity with which some People dare to assert that which they do not know. There is nothing better known among those interested in Metals than that their ordinary mixture with Sulphur, and the abundance of the

same in their Ores, is no small proof of the ores being rich. Sufficient proof is found in the example of the Ruby Silver from the famous Hill of Santa Isabel, New Potosí, in the rich Province of Los Lipes, which was almost all Silver, the same being produced with such an Abundance of Sulphur that the walls or rock between which the Metal was created caught Fire when a lighted Candle was brought near to them. All those ores which are called Galenas, Black Silver Ores, and those which carry Antimony and Pyrite are well known to abound in Sulphur, as will be shown hereafter.

The same thing happens with regard to Mercury, though in this case less noticed, because Mercury is not so visible in raw Ores, nor is it given off in the fumes of Ores subjected to heat, so that it cannot be perceived, like Sulphur, by the sense of Smell. However, its effects are well known to those who intelligently study the fumes of Smelters. For the last few years, the proof of what I assert has been clearly seen in the Challatiri mines, four leagues from this Hill of Potosí, the most celebrated and richest in the World: when their Silver Ores were smelted there was left in the Furnace not only the cake of Silver but also a great abundance of Mercury which was recovered from the cooler part of the Ashes. The abundance thereof was visible at first sight; and afterwards, when the ores were treated in a better manner, as much Mercury was recovered as from the richest rock of Huancavelica [In Peru.—Translators], where it may be that much Silver exists in the great amount of Ores which has been smelted there, although I do not know whether any ingenious Miner has made the experiment.

If the foregoing is not sufficient Proof of those Facts which are aimed at in my Argument, it is of no importance that they try to show that Metals are not composed of Sulphur and Mercury by saying that these Substances are not present in their Mines; for these, as component Parts, acquire a different nature from that in which they were created, and abandon their primitive form. But, on exam-



ining more carefully the Secrets of Nature, learned Men (not the Vulgar) recover Mercury from all Metals, which they say are palpably and visibly composed of Mercury. I do not say here how this is done, in order not to give rise to chemical Experiments, whereof the Difficulties are greater than the Profits. Common Mercury also is converted into fine Silver—the possibility and truth of which is proved by a certain Experiment made in the presence of so many witnesses in this Province that it would be reckless Audacity to give them all the Lie.

# CHAPTER TWENTY

#### THE EFFECTIVE AGENCIES IN THE GENESIS OF METALS

Besides Heaven, which, as a universal Cause, contributes to the Generation of all Things, including Metals, there is necessary for their creation the agency of another immediate Cause, with sufficient power over them to work them in their own Material; for the components of Metals are not capable by themselves of uniting, nor are they destined to the production of a certain kind of Compound, save when they are guided by another special Virtue, as is seen more manifestly in Animals. This immediate mineral Cause, or Virtue, uses as instruments elementary Forces, especially Heat and Cold, in the generation of Metals. By heat it mixes uniformly the Earthy and Humid matters of which Metals are composed, and cooks, digests, and thickens them. By heat it hardens and crystallizes them into the form of Metal, more or less perfect, according to the greater or lesser Purity which it has found present in those Elements. On this is founded the opinion of Calisthenes, Albertus Magnus and others, who say that there is only one kind of perfect Metal, which is Gold; and that other Metals (even as raw material) may be reduced to perfection and converted into Gold.

Those who deny the possibility of the Transmutation of Metals make great efforts to prove that the different Metals are of completely different Species, and that the transmutation of one into another is impossible; but they leave no one firmly convinced of their first assertion; and even when the first contention is conceded, the second does not follow, for we have seen that similar or more difficult Transmutations are made both artifically and naturally. By Art, Wasps and Beetles are produced out of Manure; and out of Sweet

Basil, properly placed and treated, Art produces Scorpions. And it is a well-known fact that in Scotland, out of pieces of the Beams of Ships, and out of Fruit fallen into the Sea, Ducks are produced. There is an incomparably greater distance between animate and inanimate things than there is between one Metal and another. Moreover, besides many other things which could be named here, it has already been said that Wood is converted into Stone by the water of certain Rivers; and in the sustainment and nourishment of living Beings transmutation is continuous; and as regards metals, the possibility of Transmutation is evident from the action of the Lipes Stone (Copper Sulphate) for, as already mentioned, by a solution of it in Water, without any Artifice whatsoever, Lead, Tin and Iron are converted into pure Copper. It may also be maintained quite reasonably that Transmutation is possible in view of the special Properties which we note in all the other Metals no less than in Gold, some of the former being in that state of permanence in which we see them all, without Nature wishing to take a step in advance and give them the Perfection of gold. And there are other reasons which might be brought forth to prove it.

The opinion against the impossibility of Transmutation, sustained by Calisthenes and Albertus, is also quite reasonable if we accept a single Definition as applying to two things which cannot be looked upon as different Species unless that which makes the special Difference between them is proved. Thus it cannot be inferred that the Lion and Man are altogether different Species, because they are looked upon as Animals; for otherwise Peter and Paul would be different in Species; the difference is one of rational and irrational Temperaments. And thus, the definition of Metal is applied to Silver and Lead as well as to Gold, Gold being perfect, and the others imperfect (though of the same Species), just as the Child can be compared, in essentially the same manner, with the fully developed Man, because the

Child may improve and develop into Perfection.

That different Properties are seen in Metals is no proof against Transmutation; these are simply the Accidents or Irregularities due to their state of Imperfection, and they may be removed. And if the stage in which they exist appear to have permanence, the same is due to the Slowness with which they grow and improve. This is not manifest to human observation in any greater measure than it is in Plants, which while we do not see them grow, we recognize when they are grown. The fact is that Man, in his Greed, snatches the Metals out of their Veins before they are ripe.

# CHAPTER TWENTY-ONE

# SEVERAL CHARACTERISTICS OF METALS

The Property of melting and again coagulating or becoming Hard is one of the Characteristics of Metals; and although it is observed in other things, it is, in Metals, of special interest. It is due to the Humidity contained in them, which, just as Cold hardened it, is melted by Fire; and according to the proportion, greater or less, in which it is mixed with the Earthy part, the Metal melts with greater or less difficulty. Tin contains much Moisture badly mixed with earthy matter; and to this latter fact is due the squeaking Noise made when the Metal is bitten between the Teeth; while to both is due the ease (exceeding that of all other Metals) with which it melts. After Tin, Lead melts with least heat; then comes Silver, which requires more heat to melt it on account of the most perfect Mixture of its earthy and watery parts, although the latter predominates. Gold, on account of its parts being better mixed, and containing fixed Sulphur, that is to say, because its earthy part is highly purified, delays longer in melting. In Iron the earthy part is impure and badly mixed; and thus when that metal is heated by fire, it is burnt and consumed; and it does not melt unless very violent heat is applied. Copper, according to some, is a metal closely allied to iron; and, although it contains more humidity, it delays in melting on account of its very refractory earthy part.

The same line of Argument may be pursued with regard to the Lustre which exists in all Metals; for, the purer they are, the more brilliant they become when they are planed, smoothed and polished. In this, as in other good Qualities,

Gold excels beyond all others, and after it Silver excels the rest. White is a colour common to many Metals, although in the case of Silver it is more perfect: I do not know with what eves Cardano saw Silver when he found it black. The white Colour is caused by the complete Mixture, subtile and penetrating, of the humid and earthy parts; for, if the Mixture were muddy, impure and combustible, it would produce a dark or black Colour, the more or less white Colour of Metals being due to their more or less perfect Mixture. Gold is vellow or red, the Colour being due to the heating effect of the purified Sulphur on its Mercury or humidity, as happens with lyes, urine and other things; the red Colour is apparently due to heating the mixture of earthy matter and humidity. The colour of Copper has the same origin; although, on account of its impurity and the burning of its parts, and their imperfect Mixture, it cannot compare with Gold in Colour, and still less in Nobility and Fineness.

Metals (since they all partake of the nature of Sulphur) have not a good Odour; although in the case of Gold, on account of its excellent temperament, the Smell and Taste are good—or at least not bad. To the same cause is due the behaviour of Metals in staining of the Hand which touches them; in this respect, also, Gold, on account of its unequalled Purity, is an exception.

Ductility, or the property of spreading out under the blows of a Hammer, is also a property of Metals. It is due to that Humidity which cedes and gives way when the Metals are beaten, causing them to spread out. The most docile in this respect is Gold; after which comes Silver, then refined Copper, and then Iron, Tin and Lead.

Metals are burnt and consumed by fire, on account of the greasy Sulphur and earthy matter of which they are composed; just as, on the other hand, they are protected from fire by their humidity or Mercury. Gold first, and after it Silver, are two metals so pure and strongly united in their components that their Humidity cannot evaporate, being protected by their earthy matter, nor can their earthy



matter be burnt, being protected by their Humidity; and for this reason they resist the action of fire without diminishing in Bulk or being corrupted. The other metals are consumed for lack of purification and union of their components.



## CHAPTER TWENTY-TWO

THE NUMBER OF METALS, AND PLACES WHERE THEY ARE BEGOTTEN

Those who humbly attribute to the Stars and Planets special influence and Dominion (besides the general effect exercised by the Heavens) over all sublunar things, credit the formation of Precious Stones to the Fixed Stars; for these the Precious Stones appear to imitate, not only in the Splendour and Lustre with which they shine, but also, and principally, in their Fineness and Permanency; on the other hand, lack of stability and constancy characterize Metals; they are found sometimes molten and sometimes coagulated, which shows that they are under special control of the Planets, called (on account of the variety of their movements) Movable Stars. Thus, symbolically Gold was designated as Sol (the Sun); Silver, La Luna (the Moon) Copper, Venus; Iron, Marte (Mars); Lead, Saturno (Saturn); Tin, Jupiter; and Quicksilver after Mercurio (Mercury). Nevertheless, as the last mentioned is not a Metal, some have replaced it in this category by Electrum, a natural mixture of Gold and Silver which at one time was considered the most precious of all Metals. But this subordination or application of names is not logical, nor is it a fact that the number of Metals is limited to Seven. On the contrary, it is highly probable that in the interior of the Earth, there are more Metals, differing from one another, than we commonly know of. Bismuth was discovered a few years ago, in the Sudnos Mountains of Bohemia; it is a metal somewhat like a cross between Tin and Lead, without being either of the two; it is known only to a Few, as may be true of many others. When we wish to

attribute something of Subordination or Concordance of the Metals to the Planets, we should remember that it is not even certain that there are only Seven Planets; to-day, with optical instruments such as Telescopes, others are seen; see the treatise of Galileo ("De Galileis") on the Satellites of Jupiter; wherein the number and movements of these Planets are carefully described.

Experience has shown, and Reason persuades us, that the most proper place for the Genesis of Metals must be Veins in the Earth; these, ramifying through its great bulk, act as the principal recipients of its permanent Humidity, in proportion to its need, just as Blood flows in the veins of Animals. The Rocks between which veins are ordinarily formed, and which we call *Cajas* (Walls), serve as ducts through which flow the united Virtues of the subterranean and celestial heat. This excites the fumes, distributes, mixes and purifies the matter of which the veins are formed, without leaving it to be diverted and to disappear in different directions. That which is between wall and wall is called a Vein.

There are veins of all classes and kinds of Ore. That portion which in the course of time has fallen from the Outcrop, or has been carried off by Rains, is scattered among hills and ravines in the form of Sueltos or Rodados (Float); and those who know best attribute the same origin to the Gold found in the sands of certain Rivers. This gold, however, was not created there, as many suppose, but in Veins, and was carried down by the water of the streams. While Ores are most usually and naturally found in veins, still, because of certain local mineral virtues, Ores are also begotten outside of veins in places called Criaderos [Ore Deposits, as opposed to Vetas, veins, and Mantos, blanket-veins.—Translators].



## CHAPTER TWENTY-THREE

#### HOW TO FIND VEINS OF ORE

Veins of ore are discovered accidentally, or by their Streams, by the force of their Currents, tear away the capping of Earth, and, if there is a vein where the water flows, it is then left bare and clean. The wind in its force sometimes uproots a Tree which grows upon the top of a vein, and thus leaves pieces of ore exposed to view. Big boulders and fragments of the hills which have fallen down (either struck by Lightning, or undermined by Rivers) sometimes produce the same effect. Rich veins have frequently been discovered when the ground was opened by Ploughs, just as, according to Justin, Gold was found in Spain. A quarter of a league from Chuquisaca, I discovered a vein of Galena on one of my farms, when I was preparing the hillside for sowing; and it may be that in many other Parts of these Provinces, which are all so rich in Ore, Fortune may have offered great Wealth to tillers of the Soil, who, through ignorance, have not taken advantage of their luck. The setting fire to Forests, either by design or accident (as Lucretius has sung in elegant Verses) not only gave news to the World of the existence of Metals, reducing them to the form in which they were recognized apart from their Gangues, but it has also been and may again be the cause of the discovery of Veins, as happened during a fire in the Pyrenees, according to the Histories of Spain.

And even lesser efforts than these suffice, when Fortune is favourable, to enable a man to become the owner of great treasures. With the slight effort made by a Horse in stamping, the animal uncovered a great mine in Goslar, as is mentioned by Agricola. While an Indian who was working

for me, half a league from San Cristobal Achacolla, was gathering some *Tola*, a bush used for fuel in this Country, one of the small roots, when torn up, left exposed a Stone rich in native Silver. The Indian having brought it to me, I discovered the vein, and I took up claims covering the hill.

In the very rich mining centre of Turco, in the Province of Carangas, at the time when its Wealth first became known, many Soldiers were gathered together. A few, who had not succeeded in acquiring any part of the veins which had been discovered, were gathered at a certain place, discussing (as is most probable) what they would undertake to do for a living, when one of them exclaimed: "If God wishes, we shall find in this very spot what will make us all well off."

As he pronounced these words he struck the ground with his foot, and the little Earth which was removed by his slight Kick left exposed to view a piece of pure Silver, the size of a small jar, which, lifted up amidst the inexpressible Wonder and Satisfaction of all, relieved them, without any effort on their part, of all their wants for the moment. The vein underneath, of rich, or rather, pure Silver, was afterwards the source of great Wealth to them and many others. The mine was called *Los Pobres* (the poor) and was the richest of all discovered in that Place, so famous for its mines.

The mine of San Cristobal de Los Lipes was also discovered by accident. There abound among the rocks at this place, small animals of the colour of Hares, called Viscachas, commonly hunted for Sport, and, in these high places, also for Food. A man who had killed one of these by an arquebus shot found it lying across a very rich outcrop of Silver Ore. He gave the vein the name of Nuestra Señora de la Candelaria (Our Lady of Candlemas). Many other claims were taken up there afterwards, which justly made that District famous; for, in view of its natural Wealth, and the efforts of the Spaniards, it became, of all the mines known up to the time of its discovery, the third richest in this Realm, precedence being taken by Potosí and Oruro.



#### CHAPTER TWENTY-FOUR

#### HOW ORE VEINS ARE SOUGHT

Besides the metallic Veins which are discovered or met with by Accident, as already mentioned, others are found through human activity aided by Art. The Colours of hills are no small indication as to whether or not Minerals exist in their interiors, as I have said in the First Chapter of this work; this is seen in all the mines discovered up to the present time in this Realm, and is apparent even to those who know least about the subject.

There is no sure or infallible rule which, without further experiment or examination, will enable the particular kind of metal contained in a hill to be determined simply by the Colour of the earth on the surface. And thus, although the material in which Gold is found is most frequently Red or dark Yellow, like to brick which has been very much burnt, veins thereof are frequently found in white *Calichal* (White Earth, Kaolin) as in Oruro and Chayanta.

The greater part of the Silver ores, and hills containing Silver, in these Provinces, in imitation of the greatest example of the kind in the World, to wit, Potosí, are reddish in Colour, somewhat like unto grains of Wheat. Such is the Colour of the Hills of Seapi, Pereyra and others in Los Lipes, which yield Copper, although the mineral-stained surface where these veins are found is more commonly Grevish and at times Red.

In the case of Lead and Other Metals, the same thing happens; therefore, the true method of discovering what is in a vein is to assay it. Ore is found as Float on the hill-sides, or as outcrop; on breaking off pieces the Miner can recognize the difference between them and ordinary Stones.

The stones are assayed, and if the ore is one that can be worked at a Profit, or gives hopes of being profitable in depth, it is mined.

When Veins are covered over, they are said to be Encapado (capped), and are looked for in this manner: In the ravines, cut by the rains, or somewhere else upon the hillsides, the Prospector ascends little by little, carrying in his hand a Hammer called a Cateador (prospector's pick), which has a point at one end of the head, made of Steel, in order to dig if necessary, while the other end is flat for breaking Stones. Carefully noting the difference between the various Stones, and breaking those which he sees do not look like ordinary ones, he may find some with a fair or slight quantity of Metal. By studying the ground, the place from which they have come is determined; necessarily this is always higher up. Stones thus found are called Rodados (Float). The hill is ascended so long as float is to be found; its disappearance is a sure sign that the Vein has been located. The same is uncovered by digging, a sure guide to it being the Float Ore found beneath the surface.

The small Springs or Brooks seen among the hills are no slight indication of the neighbourhood of Veins, as the water which flows out of the hills comes by way of the Veins.

Trees, bush and plants are frequently signs of the presence of a Vein. In such cases they appear as though planted in a line, giving signs of the Vein running beneath them. They do not grow so well, nor is their Colour so bright as that of other Plants, when they grow over metallic Veins, for the exhalations from the Veins diminish their vitality and they become thin. For the same reason, the Dew which falls on them in the morning evaporates more quickly. Snow melts more quickly on hills where there are Mines than on other hills in the neighbourhood where no mines exist; it melts more quickly also along the courses of Veins than where there are none.



#### CHAPTER TWENTY-FIVE

DIFFERENT KINDS OF VEINS AND HOW TO RECOGNIZE THEM

Although any place where Metals are found may be called a Vein, the custom has been introduced among Miners of giving the name of Veins only to those which go down into the depths of the Earth, descending straight down from the Surface or, as happens more frequently, with a slight Dip. Differing from these are the *Mantos* (Blanket veins), which enter the Earth with only a moderate Dip. These two kinds of veins are very well known, although the deepest, most common, and most frequently worked is the First. Rarer than all these are what are called *Sombreros* or *Amontonadas* (hats or heaps, i.e., irregular ore deposits) where the ore, in more or less volume, is found in a heap, without descending or spreading out sideways.

The Strikes of deep Veins are carefully studied by European Miners, as they are considered to be sure signs of the greater or less Richness and Abundance of Ore. In the first rank of excellence are placed those which run from East to West, or more or less in that direction, dipping to the South. In the second rank are placed those which run in a contrary direction, that is, from West to East and dipping to the North. In the third rank are placed veins running from North to South and dipping to the East; and of little or no good are considered those which run in the opposite direction.

Whether a Vein runs from East to West, or from West to East, or otherwise, is determined by the *Laquis*, (Splits or Branches) a term used by the Miners of this Realm to indicate the Junctions of Veins; the Strike of Veins is in the

direction indicated by the Junction of the Branch and main Vein. The Outcrop also serves as a guide to what passes underground. Similar signs are observed in Streams and Rivers which carry Gold, although, in this case, the basis of the Argument is not so good, for Gold is not created in the streams, but in Veins, which Time and Water have robbed of their Metal.

But, without saying anything against the Authority of those who have written to this effect, Experience has often shown the Contrary to be the case in Europe and in these Countries. It is probable that facts are stronger than Signs, and this Rule, like others, is not without Exception. Furthermore, the rule may be modified in view of the Southern Pole and opposite Climate of this New World, taking as an example the most famous and richest mines of the two Potosí hills.

I should give the first place, so far as Abundance and high grade of Ore is concerned, to the Veins which run North and South, on the slope of the hill looking Northwards. This is the Strike of the four principal Veins of the hills referred to, viz., the Centeno (which was the first one discovered), the Rica, the Tin Vein and the Mendieta. The second place I should give to those which run from South to North, on the hillside looking South. This is the Strike of the Veins in the second district of importance of this Realm, that famous Village of San Felipe de Austria de Oruro (Oruro); this place, in the wealth of its Veins, their great number and width, the abundance of their Ores, the extent and depth of the Workings, and the intelligent work of the Inhabitants, competes worthily with the grandeur of Potosí. Many other rich Veins, in different mining districts, run from East to West; and there are some also in different parts, the strikes of which vary greatly. The most certain general Rule in this respect, therefore, is to follow the Ore. If it is worked with Profit, or at all events without Loss, it is clear that, without risking anything, one runs a chance of winning very much. And if the Vein is very



strong, and shows some signs of Gold and Silver, even if it does not from the start yield sufficient ore to pay expenses, the Miner should follow it and deepen his workings enthusiastically, as in few kinds of Labour can such great and certain hopes be entertained of great Profit. Well-known happenings in the richest mines of these Provinces confirm this.

Leaving aside other Examples, it is sufficient to point to the rich Mines of *Chocaya*, where (as a guide and encouragment to Miners), after the Veins had been followed for thirty Years and only ore of low grade had been found, the Miners struck the magnificent Fortune which many of us have seen, and of which all of us in this Realm have heard.

Very rich indeed must be the narrow vein which is worth following, especially if its Hardness interferes with the work. If the Ore has a Quartz Gangue, and blackened Native Silver appears in the cavities of the Rock like unto Grains of Powder, even if there is only a little Metal, and the rock shows no trace thereof, this is a sign of Richness on reaching water level, as was the case (in a very notable Manner) with the vein called *Tesorera de los Pobres* (Treasurer of the Poor) in San Cristobal de Los Lipes.

If gouge is found in a shaft, with similar traces of native Silver, the object of search is very near. Good hopes may be founded on the finding of Borax, Iron-stained Rock, Orpiment or Sandarach, and, lining the walls, Iron-coloured gouge, with Clay in the middle. It is not a bad sign to strike dry Earth, if it is Yellow, Red or Black, or some other special Colour; and if therein is found some trace of native Silver, it is a very good sign. Kaolin is very promising; and to find Sand [Carbonate?—Translators] where the Metal appears is considered by Agricola to be a good sign, if the Sand is very fine. He considers Earth with Pebbles, unless it soon comes to an end or changes into something else, as a very bad sign.



#### CHAPTER TWENTY-SIX

INDIVIDUAL METALS, AND FIRSTLY, GOLD

The most precious of Metals, and the most perfect of all inanimate bodies created by Nature, is Gold-as generally desired as it is known by everybody. It is created of the Matter, and in the Manner, described as common in the case of all Metals, but of such perfectly purified and united Parts, that it is almost incorruptible; nor is there any Element powerful enough to corrupt or destroy it. It maintains its substance in the violence of a Heat which would destroy all other Metals. When it is pure, neither Air nor Water will tarnish it; neither will it rot nor evaporate when buried in the Earth. By its own Nobility, it has justly won the Estimation in which the whole World holds it. The natural Virtues which accompany the physical Qualities are most necessary to the Happiness and Consolation of human Hearts, of which this ever-coveted Metal is the Loadstone. The combined Qualities in which it excels the other Metals are briefly mentioned in Chapter Twenty-one. The property attributed to Gold in solution, of being a means for securing perpetual Youth, free from Sickness, is a mystery as far as its composition is concerned; but the good Faith of those who vouch for it cannot be doubted.

In the works of many who have written about Ores may be seen the names of divers Regions, Mountains and Rivers famous for the Gold which they produce. However, it is not my intention to increase the number of pages of my Work by transcriptions from other writings. I shall even refrain from touching upon the rich auriferous deposits of this New World, as, for instance, those of Peru; and shall limit myself only to giving Your Lordship a brief Account of

those known in the District of the Royal Audience of Charcas, over which Your Lordship so worthily presides.

There is no one who has not heard of Carabaya, which is a Region famous for the abundance and purity of its Gold, its Metal being as fine as the celebrated Gold of Arabia. It is Gold of twenty-three carats and three grains. The quantity which has been, and is still being extracted, is incredible, although that which has been taken out so far has been found by People who have looked for it only in the Rivers; only now are they commencing to work the many rich Veins. Carabaya is situated alongside of Larecaja, where auriferous Ores abound. In some of the streams in those Parts. Gold is found in the Form and Colour of small lead shot, which, when they have been melted, take the red Colour of Gold, with but little loss through the disappearance of the Crust which covered them when found. The man who discovered the Gold in this form did not know what it was until he was enlightened by a Friend whom I had advised of its true Nature.

From Larecaja to Tipuani is a region occupied by savage Indians, the same having been invaded over twenty years ago by an Expedition sent to La Paz, I forming part thereof. There so much Gold is found that the accounts of it would be incredible, were it not for the many Witnesses who have seen it, and vouch for the fact.

The real name of the city of La Paz, Chaquiyapu, which we have corrupted into Chuquiabo, means, in the native language of this Country "Farm" or "Estate" of Gold. Many mine Workings exist there, dating from the time of the Incas. It is a land well known to be fertile in Gold; and, during the rainy Season boys find Nuggets in the Streets, especially in that one which descends by the Monastery of the Dominicans towards the river. In Coroyco, and other parts of the Andes of Chuquiabo, there is Gold also in many ravines, grey on the outside like Lead.

The Cerros de la Plata (Silver Hills) of the famous Town of San Felipe de Austria de Oruro are surrounded by others



having many very strong Veins, which carry the purest Gold and were worked in the olden times. Only one of them has been worked in my time; and this was done at my instigation and in view of my advice, on the Ridge near the amalgamation plant called *Sepulturas* (The Cemetery). From the Ores of this Vein, ground and amalgamated with Mercury, no small Profits were made. The other Veins have so far not been again worked, either for want of Interest in them, or because everyone is mining Silver; or, what is more true, because it has been proved that there is not as much Gold in the Veins as might be wished, although it should not be doubted that among so many there are some very rich ones, as is the case in the best of Silver-mining Districts.

The District of Chayanta is full of veins of Gold, and there are several old Tunnels on its veins. In its river, called *Grande*, nuggets are found among the sands. The same have been found also in the Tinquipaya River, seven leagues from this Potosí.

Near the city of Chuquisaca, and within the limits of Paccha, Chuquichuqui and Presto, there are many Tunnels, from the dumps of which samples of Gold have been taken. Gold exists also in the Sopachuy River, up towards the country of the Chiriguanes Indians; it is said that certain rich gold Veins exist there which the Indians themselves offered to show last year.

The San Juan River, which flows on the other side of Chichas, along the Calchaguyes frontier, abounds in Gold. In Esmoraca and Chilleo, of the same Province, the workings of the Ancients are visible; and there are workings also in Los Lipes, in which Gold exists, in one of the hills near Colcha. There is a tunnel three leagues from that town, at a place called Abitanes, which, in the Lipe language, means Gold Mine. I am quite certain that Gold exists also in Atacama, on account of the great Abundance of beautiful Lapis Lazuli which is there produced, Gold being associated with this substance.



## CHAPTER TWENTY-SEVEN

#### SILVER AND THE ORES THEREOF

After Gold, Silver is the most perfect of Metals, resembling Gold in so many ways that even those who argue most against the Art of Transmutation, do not believe it to be impossible in the case of Silver. All that it lacks of being Gold is Colour and Weight; and these, without difficulty, could be given to it by roasting and submitting it to the action of Fire, as many people have taught, and which some accomplish in practice. In proportion to its Homogeneity and Purity, it resists the action of Fire with hardly any evaporation or consumption of its substance; and because of its ductility, it may be beaten and drawn into the very thinnest of Sheets and Wires. It would appear impossible to believe, if it were not such a common experience in the Trade, that from an ounce of Silver two thousand four hundred Varas (I Vara equals 2.78 feet) of Wire may be drawn. What is still more wonderful is that the same thing can be done with only six grains, or half a Tomin (I Tomin equals one-third of a drachm) of Gold. Ductile as Silver may be, Gold is five times more so, and when it has been beaten into leaves, it spreads so much that one ounce of it will cover ten Fanegadas (about sixteen acres), or more, of land.

Silver is sometimes formed white and pure in the mines, as wires in the rock, being then called *Machacado* ore (Wire Silver Ore); such has been mined and is still mined at Turco, in the Province of Carangas. It is also found in Choquepiña, where the Incas worked, two leagues from Berenguela in the Province of Pacajes; in a hill which I discovered and registered, half a league from San Cristobal, in the Province of Lipes; in Yaco, in the Province of Char-

cas, where, amongst its rich Copper ores, a stringer of native Silver was found in tawny-coloured rock. In the rich mines in Chocaya, in the Province of Chichas, much native Silver has been found, amongst the richest of its ores; and, in almost all the mining districts of these Provinces, ore of this kind is now and then found, full of Silver threads and spikes.

In no other mine have I seen what I noticed in Oruro: in the ores from a vein in the hill of San Cristobal, in addition to the leaves of native Silver seen in the rocks, the *Llampos* (fine weathered ore) was full of Silver as a very fine powder, which, without the necessity of any process other than Panning, could be recovered in the same way as Gold. But the most usual thing is to find Silver so incorporated in the rocks that it cannot be seen nor recognized except by the Experienced. The different kinds of ores will be described

further on, together with the treatment thereof.

The abundance of Silver ores within the jurisdiction of the Royal Audience of Charcas is so great that, if there were no other Silver mines in the World, they alone would suffice to fill it with Wealth. In their midst is the hill of Potosí (never sufficiently praised and admired), the Treasures whereof have been distributed in generous measure to all the Nations of the World. Its greatness, and that of the Imperial Village to which it gave its name, is worthy of being immortalized in a special History by great men of both Worlds. It is completely surrounded by many and very rich Mines, as, for instance, those of Porco, the famous mines of the Incas, and the first from which the Spaniards extracted Silver; those of Andacaba, the old workings of which, by reason of their Depth, Distribution and System are the wonder of the most experienced Miners. An abundance of Silver ore is assured for many Centuries, and in the extraction thereof may be employed half the Indians of this Realm. There are also the mines of Tabaco Nuño, near the famous lake [Reservoir.—Translators] of the same This artificial lake is one of the most wonderful and costly Constructions of its kind, and thereupon this



most liberal Commonwealth has spent a great part of its Resources. Sufficient water is stored in it to form a River which flows throughout the entire year, and which provides Power for the working of over a hundred Silver mills. Besides the foregoing in this Region there are also the Mines of Guariguari, Caricari, Piquifa, Vera Cruz, Siporo and many others.

In Lipes, the mines of greatest renown are the Santa Isabel of New Potosí, which in the Beauty of its hill, and the Richness of its ore, resembles Potosí itself; the Trinidad, a very rich mine; the Esmoruco, called also the Bonete (Cap) on account of the form of the hill; the Yanquegua and the Nuevo Mundo (very strong veins discovered in my time); Abilcha, Todos Santos, Oslloque, San Cristobal de Azochalla, Sabalcha, Montes Claros and many others. In the Province of Los Chichas, are the mines of San Vicente, Tatasi, Monserrate, Esmoraca, Tazna, Sabina, Choroloque, and Chocaya (the old and the new); the latter, only lately discovered, is the Admiration and Wonder of miners, and added evidence of the unequalled natural wealth of this Realm.



# CHAPTER TWENTY-EIGHT

# CONTINUES THE DESCRIPTION OF SILVER MINING DISTRICTS

The province of *Charcas* possesses, in addition to the rich Hill of Potosi (which of itself is sufficient to immortalize its name), and the other mines which have been mentioned, the mines of *Yaco* or *Cerro del Milagro*, those of *San Pedro de Buena Vista* and *Mallcocora*. Silver ore is found near *Chayanta*, in *Paccha*, and *Tarabuco*, not far from *Chuquisaca*, and in other parts. In the Department of *Pana* there are three hills close together, San Cristobal, Pie de Gallo and the Flamenca, forming the group of Oruro—an illustrious Village of this Realm. Roundabout are Avicaya, Berenguela, Sicasica, Hoya and Colquiri; the last, although it is a Tin mine, also has very rich Silver ores, called *Lliptas*.

In the province of *Pacajes* are the rich Berenguela camp, the mines of *Santa Juana*, *Tampaya* and others. In the district of La Paz are the mines of *Choquepiña*, *Pacocaba* and many others. In a word, all these Provinces form a continuous mining camp and, although the Districts so far discovered are numerous, it is known for a fact that there are many other rich places which have not been discovered on account of the diligence of the Indians in keeping their

location a secret.

The mine called *Chaqui* (so called because they say it is close to a Town of that name) is four leagues distant from this Imperial Town; it is famous throughout this Country for the stories of its incomparable Richness. It is certain that this Wealth exists, although so far no one knows where it is. The search for it has cost the lives of Indians, who,

rather than be forced to reveal its whereabouts, have committed Suicide.

Not less famous is the mine of the Encomenderos (The Agents) in the Province of Lipes. This name was given to it because it is said that the Indians, a few years ago, extracted a large quantity of Silver there, which they contentedly despatched to Spain by two Agents, Brothers, surnamed Tapias. Later this rich Province was incorporated among those of the Crown, and when I was Parish Priest there, I spoke with several of the Natives, who told me that they were the ones who had carried the Wealth of their Masters to the Port of Arica, where it was shipped. The truth of this is well established; and that their mine is hidden I do not doubt, because all the mines in that Province which have been openly worked were discovered and worked by the Spaniards, and not a single Silver mine belonging to the Indians has been met with, although it is known that they possessed very rich mines. Besides the very rich specimens of Silver ore found everywhere, the streets of the towns. when I was a Parish Priest there nearly twenty years ago, were full of pieces of Ore (of which I took Advantage), besides the rich pieces of Ore which were brought to me from unknown mines.

In the outlying parts of Yulloma, in Pacajes, they tell stories of very rich Mines known only to the Indians and worked by them. Very many pieces of Silver have been bartered in this Village and even I have managed to obtain possession of some. The Beauty and Colours of the hills make reasonable any suspicion of the kind.

Even more certain is it that there is a rich Mine near the town of Caquingora, in the same Province of Pacajes; for in its streets and in the walls of its houses there are very rich Ores—a fact of which I was an eye witness. Many other towns enjoy the same reputation; and it is said that in the time of the Incas every one of the Ayullos (communities) into which the Country was divided had its own mine.



## CHAPTER TWENTY-NINE

## COPPER AND THE ORES THEREOF

In the composition of Copper an almost constant Purple part predominates, giving rise to its fiery Colour. All Copper ores, when they are melted, smell, more than any others, of Sulphur and, on account of having been put to excessive heat, this Metal is less subject than most others to injury from the Air, Water and Earth, just as Coal is exempt from such influence. In constructions of everlasting durability it is very useful, as it does not rust like Steel and Iron; and thus in olden times it was held in high esteem, being used to make nails and screws for Ships, Arms, and other instruments—to which use it was put also by the Aborigines of this Realm.

Copper is formed in rocks of different colours, though always distinguished by spots of Blue and Green. It is begotten with Gold and Silver; and sometimes when pure Copper veins have been followed, pockets of the finest Gold have been found. Its turning into Silver is a more common occurrence, and Copper veins showing signs of Silver are generally very rich in depth, in proportion to the Water they strike. The Oslloque mine, in Lipes, was in almost pure Copper at the surface, and, as it deepened, it began to yield Silver, until it turned into pure Silver in those parts where, in spite of the great quantity of Water in the mine, the rich ore could be extracted. This is a proof of the near relationship which exists between the Metals mentioned; and that their state of greater or less Purification is the cause of the difference seen between them.

There are many Copper mines in these Provinces, and the origin or foundation of all Silver mines, as has been proved by experience, is Copper, which gives the colour to the Silver ore known as Negrillos [A Bolivian designation for black sulphides.—Translators]; for all the Silver ore veins there are just as many more of Copper. This metal is also found alone in veins which yield from the surface downwards. There are hills around Potosí with many Copper mines, although the greater part of the ores which have been and are extracted here, have been found at Lagunillas. To-day most of the Copper comes from Yura.

In Lipes, there is a large old Working in the hill called Seapi two leagues from Chuica; another, in which massive native Copper is found, is situated a league away from Sabalcha, on the highway to Colcha; and, although the metal is found in many other parts of this Province, in no place is it worked so profitably as in the hill called Pereia, and the vicinity, towards Gustacondo.

In Atacama (Northern Chile of to-day), there are very wide Veins, some extending into the Sea, and showing massive outcrops of Copper ore which rise above the surface of the water. In Chichas, in those places where there are no Silver mines, Copper mines abound; not far from Esmoraca native Copper has been found. There are also rich Copper veins in Oroncota, and among the heights of Tarabuco many old shafts and other mine workings are seen. It is found in all other parts of Charcas, and especially along the boundary of Macha, Copoata and Chavanta. It is also extracted at Tarua, near Oruro. In the Province of Carangas, the hills near Turco abound in Copper, as do also the old Indian mine workings near Curaguara de Pacajes. On the road between this town and Yullamo, many veins are seen. Some very wide veins cross the road a league from Callapa, on the way to La Paz. Not far from Caquingora there are superb mine workings, and much native Copper in a white gangue. Less than half a league from Yulloma, near the road to Calacoto, in some small hills of very dry clay, I discovered some narrow veins of Copper so pure that it looked like fine Gold; I collected a quantity from among the



loose rocks on the surface. There is native Copper at Choquepiña, near Berenguela de Pacajes. There are other virgin veins and mine workings not only on the road from Potosí to Calacoto a league and a half (four and a half miles) from the latter Place, but all over the remainder of the Province as well.

#### CHAPTER THIRTY

#### IRON

Iron is, if not the most precious, the most necessary of Metals for human Use, although it may be wondered whether the Evils it causes are not equal to or greater than its Advantages. Nature made it hard, on account of the excess of Earth or fixed Sulphur from which she formed it, though with a mixture of humidity, or Mercury; so that, in view of the former, it does not melt except at a very high Temperature, while, in view of the latter, it does not break into small pieces under the blows of the Hammer, as is the case with the hardest Rocks; on the contrary, under the blows of the Hammer it lengthens and spreads out. It is a cold and dry Metal, more porous than the others, and therefore weighs less. This is why it rusts, and is easily corrupted by Humidity, especially under the influence of Salt Water, which is more penetrating. With every heating it loses a part of its bulk as Scale, on account of its being so earthy, lacking moisture. If when it is red hot it is immersed in cold Water, it becomes very brittle, because the Heat shrinks and gathers together in its centre, fleeing from the Cold: thus is consumed or diverted a part of the native moisture of the metal which otherwise enables it to resist the blows of the Hammer, and spread out under them.

Nor is this necessary Metal lacking in this Province (so fertile in all kinds of Metals); no one, however, is occupied in the extraction or treatment thereof, because anything that is not Silver is not thought to be worth the trouble of working, and therefore all our needs are supplied by the most noble Domain of Biscay. But what does this amount to, when Copperas, Alum and Salts are, to this very day, brought hither from Spain, whereas they could be

taken hence to Spain and all the other Countries in the world?

In the valley of Oroncota there is a great Iron deposit. A wide vein was being followed in the hope that it would turn out to be Silver, and the condition and appearance of the Ore encouraged the hope. They brought me some for Assay, and I destroyed the hopes of the Owners, telling them what it was. The same thing happened with other veins on the hills near the Pilcomayo River, five leagues from the city of La Plata, although the Iron in the latter mines is mixed with Copper, and is not pure like the Oroncota ores.

Near Ancoraymes, a town in the Province of Omasuyos, there are very extensive mine workings of the Incas, which I went to see in view of their being so famous. The Ore is very heavy, hard, and of a dark colour, although a great deal of it is lustrous. The rock shows the colour of pure Blood, when pieces of it are rubbed together, like Hematite, to which class it undoubtedly belongs. There is an abundance of Iron as I assured myself by careful investigation. The Indians perhaps followed some stringers of precious Metal which traversed the baser material, though we have no proof of this. It may be also that they did not work the iron Ore, but that they simply took pieces, heavier and harder than our Bullets, to use in their slings and Libes Itwo rounded pieces of iron ore joined by rawhide thongs, like the Bolas of the Patagonian.—Translators]. They use the Libes in warfare and call them Higuayas.

In Oruro, near San Brigida, there is a vein of Iron exposed in the ravine. Some nails were made of the metal, simply out of curiosity and as samples, when I was there. The ore called *Chumpi* (Magnetite) found in Potosí hill, *Chocaya* and other mines, contains much Iron; this metal exists in great quantities in other parts; but it is never looked for, and no attention is paid to it, for the Miners care to acquire no more Knowledge than is necessary to make tests and assays for Silver.



# CHAPTER THIRTY-ONE

#### LEAD

Lead is a very common and well-known Metal; there is hardly any Silver mine where it does not exist, while it is very rare for Lead to be found without some Silver. Nature created it with an excess of Humidity, in order that it might impart the same to Gold and Silver; with Lead they may be melted and recovered; without it they are slagged and lost before reaching purity. Lead is easily dissipated by heat; when this happens it takes along everything which is not Gold or Silver, thus making it easy to refine these Metals. In weight, it resembles Gold, and in colour Silver. It mixes with both, and besides purifying them, as I have indicated, it separates them from Copper, melting and carrying them with it, and leaving the Copper apart, as will be duly explained.

It is therefore the most necessary of all metals in the treatment of Ores. A proof of its softness is the abundance of Humidity or Mercury in an impure state of which it is composed, and which the Alchemists separate from it by various and not difficult ways. It is not corrupted or consumed by the action of the Air or Water, as Iron is; on the contrary, under such influence, it is augmented and grows in quantity and weight, as is affirmed by weighty authorities; and it is even said that this Property has been the cause of the ruin of buildings which were covered with sheets of Lead. It is at times found mixed with Gold, but more commonly with Silver; and sometimes it accompanies Copper. The most common Lead ore is called Soroche (Galena). There are also other black, crusty, lustrous, or dull-coloured ores; the latter are called Muertos (Dead Ores) and also Oques,

meaning "Monkish," referring to the sombre colouring. No Silver District has ever been discovered in this Realm in which Lead has not been found; thus there is no necessity to repeat the names of the Places where it is found. The greater part of the Chichas mines carry Lead, for which reason Smelters are so common in that Province. The mines of Andacaba are of a similar nature; and, as the Ores are not suited to amalgamation, and Wood is lacking for smelting purposes, their production has so far not been great. These are among the most abundant and richest mines, in my opinion, of this Realm. On the slope below and to the west of Potosí, at a place called Sibicos, there are a number of Lead veins, with very little Silver; and the same sort of veins exist to the westward of San Cristobal de Oruro.

## CHAPTER THIRTY-TWO

#### TIN

What we call Tin is known to many as Plomo Blanco (White Lead) and the same name is given by Refiners to the Lead liquated from Silver and Copper, as will be explained hereafter. They resemble each other in Colour, and the squeak which is produced when they are bitten or broken. Common Tin is of the same origin as Lead; but, because its constituents are purer and cleaner it is whiter and harder than Lead; on account of the imperfect mixture of its constituents, it squeaks when bent and for that reason is called a Crying Metal. It is poisonous to other Metals, and all those which are mixed with it become brittle; because, when combined with it, they lose that perfect union of their parts which characterized them before, and their Malleability is diminished. Lead alone does not suffer in this way, because, on account of its excessive Humidity and Softness, it penetrates and mixes with the badly mixed parts of the Tin, and thus the Allov remains malleable.

Tin ores are not by any means common; but they are not lacking in these very rich Provinces. The Colquiri district near Oruro is famous for the great quantity of good Tin, which has been and is still being extracted, to supply the whole of the Realm. Associated with the Ore, as has already been said, are found at times rich pockets of Silver. Near Chayanta in Charcas there is another Tin district, from which a great abundance has been extracted for some years past. Not far from Carabuco, one of the towns on the shores of the great lake of Chucuyo, near the limits of the Province of Larecaja, there are Tin mines which the Indians worked in the times of their Incas, and which were after-

wards worked by the Spaniards. They are powerful Veins, and rich in Silver, and all of them contain some Copper, on account of which Mixture this Tin is of better appearance, and hard. The fame of the richness of these Veins led me to visit them, impelled by the interest I have always had in seeing and examining the mining Districts of all the Provinces. In the hill called Pie de Gallo de Oruro, there is a great deal of Tin, although few recognize it; not finding the Silver of which all are in search, they throw the Tin ore aside.

One of the four principal and rich Veins among the great multitude which exist in this unequalled hill of Potosí, is the one called *Estaño* (Tin), on account of the great quantity of Tin found in the surface Ores; later the vein turned into Silver on account of the more favourable vein matter. Also in this Parish of San Bernardo, of which I am at present the Incumbent, and about a quarter of a league from the Church, there are very rich Tin mines, which Your Lordship went personally to see, in view of the information I furnished regarding them, thus encouraging, as you have done in many other ways, those engaged in the Mining industry, by which His Majesty's Royal Treasury and his Vassals have been so greatly benefited.



## CHAPTER THIRTY-THREE

#### MERCURY

Mercury, a very well-known Metal, is a liquid body which runs like Water, composed by Nature of a viscous and very subtile substance, with much Humidity, because of which it is very heavy, very lustrous and very cold (according to most Authorities). There are not lacking some who affirm that it is very hot, in view of the effects resulting from its great Subtility and Penetration, which enable it to pass not only through Flesh but also through the hardest Bones. It is also thought to be hot, because, as is well known, Corrosive Sublimate is a poison on account of this being hot in the highest degree. Solimán (Sublimate) is nothing more than Mercury, though essentially altered by the admixture of metals with which it was cooked and sublimed; and it is a fact that Corrosive Sublimate may be (and it is) reduced back to real Mercury in a way which will be described later. But, leaving this to those who investigate the Properties of the Elements, the fact is that Mercury has so much in common with the other Metals that, although it is not any one of them, it is convertible into all, not only on account of the Principles of which it is composed (as most Philosophers affirm, and as they prove by the facility with which it unites and incorporates with all other Metals), but also because it can be wholly transmuted into real Metal, like those which Nature bore, and behaves like Metals under the action of heat and the hammer. Raymond explains a number of ways by which it may be converted into Gold and Silver. There is a very easy way, explained in the discourse of Eliana, for converting it into true Lead. Although judgment may be suspended as to the credit to be given to Writings

which may possibly not be understood, there are many Eye-witnesses in these Provinces, who to-day have and hoard Silver in large quantities, made out of Mercury with the help of Cupellation, by their own hands. Although the Reagents were furnished by others, there is no room for

doubt as to the possibility of this transmutation.

Very few were the uses to which Mercury was put, and its consumption was very limited before this age of Silver. It was used only in the form of Corrosive Sublimate, Cinnabar or Vermillion, and as Red Oxide powders called Juanes de Vigo. But when it is employed to extract Silver from finely-ground Ores (a process but little used in olden times). it is incredible how much of it is consumed. While the quantity of Silver extracted in this Realm has been enough to enrich and amaze the Universe, it is also true that an equal quantity of Mercury, if not more, has been consumed in the process; for although to-day, at the cost of excessive losses, experience has been gained which permits the more economical use of Mercury, the Miner who is most skilful in the extraction of Silver by its aid loses a weight of Mercury in the operation equal to the weight of Silver he extracts; and frequently he loses more. What the cause of this is. and (what is more important) the Remedy, is one of the aims of this Work, and will be explained hereafter. The treatment of ore by Mercury was introduced into Potosí in the year 1574; and, up to this Present, 204,700 Quintales (10,235 short tons) of Mercury have been brought to the Royal Store-house of this Imperial Village for account of his Majesty (without counting the large quantity of Contraband which has been consumed).

For this exceedingly great consumption, God has provided us with the great Quicksilver deposits of Huancavelica (in Peru); and in these parts, within the Jurisdiction of Charcas, the Minerals of which I have wished especially to describe to Your Lordship, this Metal is not lacking among the Abundance of others. There are Mercury mines in Chalatiri, four leagues from this Imperial Village. There



are also some near Guarina, in the Province of Omasuyo; and, not far from *Moromoro*, which is an Indian town, seven leagues from the town of Chuquisaca, some rich Quicksilver ore was found; but, on account of the sudden Death (not without suspicions of Violence) of the man who tried to discover the Mine, the same has remained concealed to this Day.

# CHAPTER THIRTY-FOUR

# ALLOYS, AND ARTIFICIAL METALLIC COMPOUNDS

Art has also its Metals, and, in the Variety and Multitude of metallic things manufactured by its aid, it imitates the beauty of Nature. By mixing of Tin and Copper, Bronze is produced for bells, cannon and other things. For this, one pound of Tin is mixed with from four to eight of Copper, according to the object for which it is intended. The Indians were acquainted with this mixture, and it served them for giving strength to their Instruments and Arms, even as we make use of Steel and Iron, of which they were ignorant.

Brass is made of small pieces of Copper placed in adequate crucibles and covered with *Calamina* (Calamine) a yellow earthy mineral, found not far from Turco, in the Province of Carangas, and also near Pirantora, in Charcas. Over the powdered Calamine a large quantity of fine Glass is placed. Heat is then applied, the Copper changes colour,

and increases in volume by eight per cent.

Various mixtures are made for Mirrors, although the best is composed of two parts of Silver and one of Lead. Besides those mixtures, Cinnabar, Corrosive Sublimate, Red Oxide of Mercury, Red Lead, Enamel, Slag, Cadmium, Smelter Fume, Flowers of Copper, Copper Scale, Verdigris, Copper Oxide, Iron Scale, Iron Blue, White Lead, Ochre, Litharge, Tin Purple and Glass are produced artificially.

Cinabrio (Cinnabar) is made with one part of Sulphur and two of Mercury, heated and sublimed together in

vessels of Glass, or of glazed Earth.

Solimán (Corrosive Sublimate) is also made of Mercury, mixed with an equal quantity of Copperas, ground to a fine

powder, and mixed with a little strong Vinegar to make a mass. This is sublimed in Glass vessels. Alum is also used for this purpose, and often Salt is added.

Mercury is dissolved in Nitric Acid; if the solution be evaporated over a slow fire, the Mercury is left behind as hard as a Rock. Powder this very finely, heat it again in a crucible over fire (this is best done in a Copper vessel), and stir it until it becomes a very bright red. This is the *Precipitado* (Red Oxide of Mercury).

Itch cure consists of two parts of Copperas and one of Litharge; they are ground and mixed with a little strong Vinegar, and left in dung for forty days. The mixture is then toasted in an earthen pot until it becomes very red.

The best Enamel is made of Alum, Copperas and Rock Salt. All colours are given to it, as to Glass.

Slag is the substance which is separated from Metal when the latter is melted; it floats on the surface of the molten Metal as if it were Grease. It is the *Diaphiges* of Latin authors.

Cadmium (of which there is also an Ore) is found sticking to the sides of the furnaces, especially when Copper is smelted. It is called *Botryitis* when it is nodular; *Stacita* when it looks like earthenware; and *Placite* when it looks like bark.

Pompholyx (Zinc Oxide) is a flour-like or woolly substance, which falls to pieces on being touched. It sticks to the walls of furnaces when Metals are smelted, and the vulgar name for it is *Atutia* (Tutty).

Between *Pompholyx* and *Spodium* there is very little difference. The latter is the more impure, and is found on the walls of furnaces in which Metals are refined.

Copper Flour is made by pouring cold water on hot Copper plates as they are cast from the fore-hearth. Very fine particles rise in the form of smoke, and are recovered on the faces of Iron shovels.

Copper Scales are the pieces which are broken off from the Metal when it is hammered and beaten. The scales



which are broken off from Iron in this way are called *Stomoma* by some, although this Greek word more properly means Steel.

Cardenillo (Verdigris) [Cardenillo also means Red Oxide of Copper—Translators] is made of Copper by covering vessels containing strong Vinegar with lids of Copper, the Verdigris forming at the end of ten or twelve Days.

If, instead of Copper lids, in this process, Iron lids are

used, Herrumbre (Rust) is produced.

Verdigris is very similar to that substance which is called Vermicular. Take one part of white Vinegar and two of rotten urine, and place them in a copper vessel or mortar. Mix them well until they thicken; then add Salt and Alum (about one-twenty-fourth of the whole) and expose to the heat of the Sun until it coagulates and dries, when the mixture takes the form of little Worms, from which it derives its name.

Blue is made by placing thin quicksilvered tin plates, full of holes, in hot dung over a vessel containing a little sal ammoniac. The blue is scratched off at the end of

twenty days.

If lead sheets are placed over vinegar, White Lead is formed. Place White Lead in an Iron spoon or vessel over a fire, and mix or stir it up well until it becomes very red. This is *Sandix* (Red Lead).

Yellow ochre is lead heated until it takes the colour of

this substance.

Greta (Litharge) is produced in the refining of Gold and Silver.

Purpurina (Tin Purple) is like Gold Purple, though not very permanent. Take four to six parts of Tin, and as many more of Mercury, one of sal ammoniac and another of Sulphur. Powder them, mix in a glass vessel, and heat. That which remains at the bottom is Purpurina.

The last place in this list we shall give to the most beautiful product of Art, which is Glass. It is made of two parts of transparent Sand or powdered Quartz and one of Nitre,



or Rock Salt or Soda, made from the Glasswort. Clean and purify by mixing in a little Loadstone. Another mixture is two parts of the Ash of glasswort and one of the aforesaid Sand, with some Loadstone, melted with the required heat in appropriate furnaces.

## CHAPTER THIRTY-FIVE

# THE COLOURS OF ALL MINERALS IN GENERAL

In order that the less Experienced may the more easily acquire a Knowledge of the mineral substances which they may encounter, and by the sense of Sight (the most reliable of the senses) recognize what they find in their Mines, I shall give the Colours of the best known of all the varieties of metals. Of a White colour are some kinds of Clay, Alum, Asbestos, Arabian Stone, Judas's Stone, Fuller's Earth, Alabaster, Crystal, Diamond, Silver, Mercury, Tin, and Marble. Of a Black colour are Bituminous Earth. Jet, Copper Oxide, and Graphite. Of an Ashen colour are the Earths of Erithria and Melos. Of a Blue colour are Sapphire, the Cyanite, the Turquoise, the Lapis Lazuli, and Azurite. Green are the Emerald, Agate, some Borax, Clays and Copperas. Yellow are Gold, Ochre, Chrysoprase, Chrysolite, and Orpiment. Red are the Ruby, Garnet, Balas Ruby, Onyx, Sandarach, Coral, Iron Alum, Hematite or Bloodstone, Copper, Vermillion, Lemnos Earth and Red Ochre. Purple.are the Hyacinth and the Amethyst.

The Jasper is light Blue. Of Greenish Blue are Verdigris and Armenian Stone; painters use the latter to make a Greenish Blue. Aphrodisiace (?) is reddish White; the Janto (?) is bright Red, tending to White; Batrachites is between Red and Black [Wrong; see Pliny.—Translators.] Manganese is purplish Black; Topaz is yellowish White. Some minerals are of many colours, such as Agate, of which there are Black, White and Coloured varieties. Apsyctos (?) has red veins spread over a dark ground, while Nosomite (?) is stained with black veins on a red ground. Heliotropia (Bloodstone) has its beautiful green field crossed by blood-

red veins. A brilliant golden sheen may be seen in Sapphires and Lapis Lazuli. Two veins, white and red, run parallel across *Egitilla* (?). *Eupetalos* is of four colours: blue, red, vermillion and apple-colour. *Orea* (?) is also found in as many colours: red, green white and black.



## CHAPTER THIRTY-SIX

#### THE PROPERTIES OF VIRTUES OF MINERAL THINGS

I shall end this Treatise with a brief account of the Virtues possessed by mineral Things, from the point of view of Medicines for the human Body, besides their Properties as already described, in order that those who have to work in Ores may know how to take advantage of them. Some minerals operate by virtue of the occult Property of their Essence, others operate by virtue of their elementary Qualities in opposition to the bodily Ailments (when taken internally). Of the former, some are antidotes for Poisons, and others are remedies for different Maladies.

Amongst those mineral Things which are antidotes for Poisons, some cure Persons afflicted with the Pest; such, for instance, are the Emerald, Lemnos Earth and Armenian Earth. Others are an antidote for one particular kind of Poison, Sapphire in solution being a remedy against the bite of the Scorpion. Sulphur, Saltpetre and Copperas are good in cases of poison by Toad-stools. Salt, as a Plaster, is employed against the bite of the Viper and the Scorpion, and is taken internally to counteract the effects of Opium and Toad-stools.

Of those which by occult Virtue cure certain Maladies, some staunch the blood in any part of the body, such as Hematite. Others, like the true Jasper, strengthen the Stomach, when they are hung over the latter from the Neck. Others, such as the Aguila Stone, called by the Greeks "Astites," if tied to the left arm, prevent abortions; when tied to the left thigh, this stone has the contrary effect; this is also true of the Jasper. Others, like the Loadstone, purge thick humours; others, such as the Armenian Stone

and Azurite, dissipate Melancholy. Others, such as the Armenian Stone itself, Borax, Copperas and Oxide of Mercury, provoke nausea.

Among the minerals which have an active effect on the human Body (and nearly all minerals are astringent), some heat the body, as for instance, Alum, Copperas, Copper compounds, Fuller's Earth and Verdigris. Others cool the body, such as Earth of Erithria, Antimony, White Lead and Litharge. Others, with the secondary properties which they possess, soften the Tissues, as pitch does on account of the great portion of bitumen which it contains. Others, on the contrary, harden the Tissues, such as Lead and Antimony ores. Some open the Pores of the skin, as for example, Nitre and Aphronitre; others, such as Earth of Samos and any other viscous and tenacious Earth, close them. Some, such as Sandstone and Pyrite eradicate Warts, Wens and condensed Gums in the body; others, such as Copperas, and Alum, dry Ulcers. There are some, such as Asiatic Stone (?), Copperas and Verdigris, which eat the flesh, and others which rot it, the latter being Quick Lime, Orpiment, Sandarach and Borax. Corrosive Sublimate, Orpiment, Sandarach and Quick Lime also rot the entrails, while Plaster of Paris, White Lead and Calcined Talc are also poisonous because they suspend the function of the bowels.



### SECOND BOOK

OF

## EL ARTE DE LOS METALES

#### CHAPTER ONE

IN WHICH THE READER IS TAUGHT THE COMMON METHOD OF TREATING THE ORES OF SILVER BY AMALGAMATION, WITH NEW PRECAUTIONS FOR ITS USE

The treatment of Ores should not be practised except by him who understands it, and after Examination and License of the Authorities. Such is the Abundance of all kinds of Minerals with which God has enriched almost the whole of these Provinces of this New World (through which can be appreciated the other high Benefits of His Divine Providence), and such also is the Fertility of its Veins, that the very Greatness thereof makes it hard to credit.

More than four hundred and fifty millions of pesos is the sum that the famous Hill and Imperial Village of Potosí has already given, a sum of which scarcely anyone would be able to conceive, and which would be sufficient to build another very great and beautiful Mountain of Silver. In order to be understood by those who know but little of this enormous Machine (as I may well name it) for the production of Riches, I would ask them to imagine the ground covered with Pieces of Eight (Reales.—Eight Reales equivalent to one peso), so that they would lie as close as possible, one unto the other. In this way they would cover sixty leagues of road, counting twenty-five Pesos to each Vara in length, and five thousand Varas to the Spanish League.

This great yield has been the reason for the lack of attention to the Losses which have occurred in the treatment of Silver Ores. These losses, without the need of exaggeration. would augment by many millions the ciphers of what has not been recovered due to lack of knowledge concerning the nature and differences of the ores. They have been treated in a haphazard manner, without a fundamental and definite Knowledge of the Silver which they contained, and which should have been recovered by those charged with the task. This waste is proved by the enormous losses of Quicksilver, the consumption of which up to the present in this Imperial Village amounts to more than 234,700 Quintales (11,735 short tons). I do not know whether one should praise the magnanimous Minds (which this superb Climate creates), for their disregard of the Crumbs that might satisfy the hunger for Riches of many Kingdoms of this World, or if one should condemn the Neglect of such a prudent and wellgoverned Republic in not making an end of this useless Prodigality, through every possible means.

The first and most fundamental of all Precautions (as I see it) is that the post of a Treater of Ores be filled only by one versed in the Art, and then only with license of the Authorities and after passing an Examination: the more so, because there are other trades under the obligation to do thus, whose Errors are, beyond comparison, of much less importance. But little thought has been given to this, up to the Present, by the Owners of some mills, because to them it has seemed that what they lost of their own Ores they still possessed for later treatment in the stored Tailings; and, in respect to the Ores of others, the worse they were treated the greater the advantage derived therefrom. Poor arguments are these both: the First on account of the doubled Work; the Second on account of being harmful to the Community, though not impossible to understand.



#### CHAPTER TWO

WHICH TREATS OF WHAT THE METALLURGIST SHOULD BE,
AND WHAT HE MUST KNOW

Most weighty is the Confidence placed in the Metallurgists, because all the Riches produced by this most prosperous Land are entrusted to them, without reckoning or Account of what part thereof they are bound to return. Their Reputation is the only assurance of their Truthtelling as to what the ores have yielded. There is neither dispute over their sentence nor appeal from it; which is the strongest of Reasons why the urge of their own Interests may incite them to take of the yield unto themselves. Much need of a Christian Honour have they who enjoy these endless Opportunities, having, as the saying goes, "their hands always in the Dough," lest some of it stick. With much caution should one look upon him whom he would charge with the task of treating his Ores, because there is no bad Substance which might hinder recovery, nor any consumption or loss of Quicksilver (both frequent and sure causes of Loss) which can cause such loss as a Metallurgist with a bad Conscience.

Nor is it alone sufficient that his good Habits be examined and approved, if there is lacking the necessary Knowledge of the Art which he must exercise. He must be able to recognize the Ores, their qualities and differences; to determine which are most fitted for Amalgamation and which for Smelting, or if there should be a combination of the Processes. He should know the harmful Substances which accompany ores, and not be ignorant of the way to remove them. He should know the Accidents which may happen to Quick-silver [Fouling and flouring?—Translators], and the ordinary

way of milling on a small scale. And, in all cases, he only can be considered as a treater of Ores, who knows at least how to make a small-scale Fire-assay of finely crushed Ore before amalgamating, in order to determine the Silver contained, and to know of a certainty and not through guesswork what he should recover. No Diligence should be omitted to secure this result.

Many ducats has the ignoring if this Advice cost this Kingdom; and even to this day we pay the damages due to the disregard of that Precaution. I will refer to two cases which have passed through my hands, in order that this may be better understood. A few years before I betook myself to the Province of Lipes, a Miner there was working, in a certain place called Yanquegua, a vein from which he had taken a quantity of very rich Ore, although he did not recognize it. Assayed on a small scale with Quicksilver, it vielded from four to five pesos per Quintal, and at this rate the whole lot yielded when milled. He abandoned the mine because it did not pay. Afterward an Indian showed it to me, and, having found ore in the waste dump and in the vein which was but little worked, I assayed it by Fire, and it had nine hundred pesos to the Quintal, although by an ordinary Amalgamation assay it came to no more than four or five pesos. I legally located this Vein, which I named Nuestra Señora de Borgoña. At once I erected a mill close to it; whereupon Miners flocked thither and worked many other veins, from which they took large sums in Silver.

In the hill of Santa Juana in the District of Berenguela de Pacajes, there were taken out some ores like Sulphides, which by the ordinary amalgamation assay showed no silver or very little; they were thrown away by the Miners, until a friend of mine, a Priest, sent me a sample to Oruro, where I was at the time. I assayed the Ore and found it to have sixty and more pesos to the *Quintal*. My friend picked up, on my advice, a quantity of the Ore, accompanied by the Laughter of those who saw this entertainment, but who later envied the great Riches taken out by him.



#### CHAPTER THREE

THE RECOGNITION OF ORES, AND THE DIFFERENT KINDS
OF ORES THERE ARE

Most difficult it would be to try to give written Rules for the recognition at sight of Ores, to those who never have handled them. Moreover, so great is their Diversity that it is rare that one Stone from a vein will resemble another. and this not only in different mining Districts, but even in the same Camp. Notwithstanding this, the Miners have reduced ores to three general Kinds, or general Divisions: these are Pacos, Mulatos and Negrillos. Paco (Oxide), in the common language of this Land means a reddish Colour, which, more or less burnt, is the ordinary colour of Stones. Therefore, ores of this colour are called Pacos, although this name also is applied in Berenguela de Pacajes to green Copper ores. In these Provinces, ores of whatsoever colour (except they be Steely and Brilliant) are called Negrillos (Black Ores). Mulato ore is midway between Paco and Negrillos, Nature having created it thus between the two; it is dull in colour and ordinarily it is accompanied by some Pyrite. There is less of this than of the other two sorts.

Negrillos get their name from, and are recognized by, their Colour, although not all black (Silver) ores are comprehended in the name of Negrillos. Tacana, a rich ore, is ordinarily black; when brown and ashy, it is called Llipita, and belongs to the class of Pacos. Plomo, which is the name given to native Silver when it may happen to be black or ashy brown, also belongs to the Pacos. When it is green, or white and orange-coloured it is called Suco (Chloride). And in the past year there was taken out of this Hill of Potosí an ore of the most florid and vivid colour of Cin-

nabar or very fine Vermillion (Ruby silver), a thing which I

have never seen in other mining district.

The Soroches (Galenas) by themselves might constitute a fourth class of Ores, but they can be grouped with others which are similar, under the name of Negrillos. To this class also may be assigned Rosicler (Proustite), the richest ore which Nature creates under the appearance of a Stone. It is shining and easily broken; the fine powder resulting, when it is broken by whatsoever hard substance, is of the finest blood-colour. It is very like unto the Cinnabar or Vermillion which one makes from Quicksilver and Sulphur, and which gives one so little thought of greater Secrets [Probably referring to Alchemy.—Translators]. Cochizo (Pyrargyrite), almost of this same class, is a very rich Ore, solid, not so easily broken nor so leafy as Ruby Silver; it is darker, and does not give the pronounced and perfect

colour of Blood, like Ruby Silver.

By that which follows one may distinguish the ores called Soroche, Tacana, Polvorilla, Rosicler, Cochizo and Negrillo: Soroche may be black and shiny, or ashy and without life, when it is called Dead Ore of Lead; it may carry Silver. Tacana (Silver Sulphide) is Silver hidden by a solid black colour, without any Shine whatsoever. Polvorilla is Tacana which is neither massive nor stone-like, very rich in Metal. Pacos mixed with Negrillos are not so rich, on account of the mixture with Copper. Rosicler and Cochizo are Silver hidden by a Varnish, which gives to them a colour and lustre that distinguish them from Tacana. Negrillo prevails principally with Copper, either as Copper metal or with Copper Sulphate, where it may be abundant. It carries more or less Silver and is commonly accompanied by Pyrite. A black ore which is heavy, smooth, and leafy or feather-like has much Alcohol or Antimony. In some parts it is called Mazacote; it carries but little Silver. The kind which is said to be mirror-like and steely, on account of its greater likeness to a Mirror, or to polished Steel, is the richer, and approximates the more to Rosicler.

## CHAPTER FOUR

THE SHOVELLING OVER OR SORTING OF ORES, AND THE PROPER METHOD WHICH SHOULD BE APPLIED TO EACH CLASS OF ORE IN ITS TREATMENT

A good beginning toward recovering the Values of Ores is made by first sorting them. The lack of this is a thing which has caused much Damage and yet it has been given but little Thought. There has been shown a lack of Investigation, not only in that the Ores have not been set apart from the Stones which are not ore, but also in that the same Ores have not been sorted out the one from the other, according to their differences and kinds. The lesser damage has been in the treatment by amalgamation, through the unnecessary transport, the milling and other expenses, and loss of time in treating that which was not ore; the greater damage was that in treating waste and ore, the ore value was not recovered. Frequently ores have been treated together which required different methods and different periods of treatment. To amalgamate ore which requires smelting is to lose it. To charge in the furnace that which is not adapted thereto is to disturb, damage and accomplish nothing. Even if the Ore be such as to fall within the province of Amalgamation or Smelting, still there are differences and degrees of easy treatment (if the ores concord in the method of treatment) which may be dangerous if there is necessity to treat them differently. Paco (Oxide) ores which have nothing that shines or reflects light are those adapted to Amalgamation. Tacana (Silver Sulphide) also comes under this Class, although, on account of being a rich Ore, in order that nothing may be wasted, and that nothing may be lost in tailings, it is best to smelt it on a

Lead Bath. That which is called *Plomo* (Native Silver), if it is exceptionally coarse, does not grind well nor is well taken up by Quicksilver, should be set aside for smelting with *Tacana* (Sulphides). The proper treatment of the finely crushed *Plomo* (metallic Silver ore) is Amalgamation, the treatment for galenas is Smelting. Ruby Silver and *Cochizo* should be smelted like Silver Sulphide. *Negrillos* [Sulphides in general.—*Translators*] are more adapted to Smelting than Amalgamation, although all may be prepared by fire for giving up their Silver by Amalgamation, after they are cooked or roasted, as will be explained farther on.



## CHAPTER FIVE

# THE RECOGNITION AND REMOVAL OF THE BAD SUBSTANCES IN ORES

Various, and of many different Qualities are the things which, jointly with Ores, Nature creates in her veins, either by abortions caused by human Greed, in taking them out of the entrails of the Earth before their due time, when otherwise, if duly seasoned in them they would result in perfect Ore; or, it may be that they are taken out as a superfluous excrement resulting from the generation of all sorts of Ores. These are Salts, Alums, Vitriols, Sulphur, Orpiment, Dragon's Blood, Antimony or Alcohol, Bitumen, which is called Grasa (Grease), white or black, and Pyrite. Few are the ores extracted which are not mixed with one or more of these Disturbers, and all are damaging when it comes to recovering the value, either by Quicksilver, or by Fire.

The Vitriols, to which class belong those called Copaquiras (Copper and Iron Sulphates) are mortal enemies of Quicksilver; they render it useless and consume it, and the more so if their evil disposition is intensified by mixing with Salt, because their penetration thus becomes more violent and quickened. This natural Antipathy was well known to, and written about by, the most learned Raymond. Every day this matter is touched by those who treat Ores, but they do not stop to think about it. Copaquiras devour Quicksilver, lower the yield, and cause the loss of Silver which is so costly in treating the ores which contain Iron, Lead, Tin and Lime. He who would care to show himself quickly the Truth of this may mix an Ore with some ground Vitriol and add a little Quicksilver; he will see after the first Grinding that the Quicksilver is floured and that all is lost

in an instant, the more quickly if a little Salt is added. This is not marvellous to those who know that Solimán (Sublimate) is Quicksilver, and that the great Transmutation in the mix was caused by the Vitriol and Salt with which it was mixed and sublimated in the heat of the Fire. This Vitriol is the worst Poison found in the treatment of ores with Quicksilver, although there are times when it may be utilized, and serve as an antidote with some sorts of ores, which demand it, as will be explained in the proper place.

With much ease this trouble is recognized, and remedied. Grind up a little of the Ore, throw in pure Water [Free from sulphates.—Translators]; stir it, and allow to settle somewhat; pour the clear Water into another cup, without stirring up the sediment. On testing it, there will either be no taste, or a styptic and sharp taste. Further, he who would care to add to this testimony that of Sight, may heat over a slow fire this (clear) Water, until it is evaporated, and he will see with his own eyes, in the Sediment which remains, the Alum or Vitriol. Wash the ore in the way indicated as many times as may be necessary, until the Water comes off sweet, or until, when it is stirred with a clean Iron, the same is not covered with the colour of Copper. Thus it will be exceedingly cleansed, and of a surety the Quicksilver will not be damaged through this substance.

Sulphur, Pitch, and Antimony, although they frequently show their presence to the Sight, prove it better through the odour they give off when burnt in the fire. However, they may be more satisfactorily recognized and removed by the following Procedure: After the Ore has been coarsely broken, it is placed in a vitrified clay Jar which has in the bottom many small holes. The mouth is then closed, and the jar is adjusted in an Indian wind furnace, which is fired in the same way as when Amalgam is retorted. Underneath the aforesaid Jar is another which contains Water, and into which it fits. In this lower Jar is collected the smoke which comes through the holes in the bottom of the upper Jar.



On examination one may see, solidified and swimming on the Water, the Sulphur, Antimony or Pitch, each one in its proper form.

The fact that no more smoke issues forth is a most certain Sign that the Ore is freed from these impediments, which, while in the crude ores they may not directly affect Quick-silver, will affect it through that Varnishing (Fouling) which they cause, preventing the Quicksilver from uniting with and recovering the Silver. Further, there is the rapidity with which, through the glass-like quality inherent in all Ores, the Quicksilver is cut up and dissipated into a white powder (Floured), when the Ore is ground. It is necessary to roast these kinds of Ores, even to sintering, before charging in the strong fire of the Furnace; because without this preparation the Silver will be converted into slag.

Pyrite is easily recognized in the Ores which carry it. Through its weight and glassiness it helps to flour the Quick-silver in milling. With fire its avid and evil Influence may be removed by roasting it until it has lost its lustre. Where it most disturbs is in the smelting of ores. On account of the abundance of impure Sulphur contained, and with which it is begotten, there is formed a blanket in smelting, which fouls the bath.

#### CHAPTER SIX

#### GRINDING THE ORES

The grinding of Ores is precisely the preparation necessary to get out by Amalgamation the Silver and Gold contained therein. It is very necessary that the pulp be fine, to shorten the treatment and recover the Silver that may be contained. One error, among others, to which but little attention has been paid by the majority in this Country, is that of grinding too coarsely, or to the state of Sand, instead of to Slimes. But little is needed to convince any person that Quicksilver attracts and incorporates into itself only that Silver with which it is in immediate contact, and that that which may be inside of a grain of Sand will remain there with the so much greater or lesser loss, as the Ore may be more or less rich, and the pulp more or less coarse. Various experiments I have made in regrinding these Sands. and the least that I have found has been around a sixth of the Silver recovered in the original treatment. means an enormous sum in each year, and it is incredible what it means in the years gone by, in which we have milled so much rich Ore. Georg Agricola, after showing the method of grinding and screening Ores, as practised to-day in treatment plants, is explicit in stating that the reduction to the finest of Flour should be done in a mill, with stones like unto those of flour mills. To him this fine grinding did not seem justified, as its object was very different to that sought in our practice, in which fine grinding is precisely and clearly necessary. [Barba probably refers to coarse grinding preceding concentration of sulphides, as against fine grinding or sliming for amalgamation.-Translators.

I know a person to whom the taking advantage of this Advice meant many Ducats, when he reground a quantity of sand tailings which the stamp did not crush fine enough. either because the Ore escaped the blows, or the particles defended themselves, one through the other, against being crushed. To have good Screens and to be careful in taking them out means much, but it does not remedy everything. After the clean-up, especially if the Ore was rich, he will be doing wisely who collects and retreats the Sands. If he roasts the Sands he will obtain more fine Sand because (for one Reason) the Ore becomes softer, and (for another Reason) it becomes spongy and presents more body on which the blow of the stamp may act. I use another treatment, by calcining, which will be discussed later. It is better adapted for all milling by Amalgamation. The ore, being ground and screened, is thrown into a hand-tub, as if it were already a pulp to which had been added the requisite quantity of Quicksilver. To wash it, throw in sufficient Water, and stir it up very well with the paddle. All the fine will be suspended, and the coarser, or badly ground, will be on the bottom. Take out the slimes with Bateas, throw into cauldrons and boil. The coarse sand is reground, either in Arrastras, or in some other grinder, until all is reduced to a fine Flour. If it is desired to make up charges of the slimes to be treated in the ordinary way, they should be mixed with clean fine Sand in order to make them porous and avoid the inconveniences of slimy ores.



#### CHAPTER SEVEN

#### ROASTING ORES

To secure two Results it is of importance to roast Ores, either that they may grind more easily, or to put them in such condition that Quicksilver will embrace and become incorporated with the Silver. The reason of the First is clear, and experience of the Second is common, especially as by this method the black ores (Negrillos) are treated. However, the fundamentals of Roasting are generally unknown, and there has never been any other thing carried on in such a careless, happy go-lucky and unscientific manner. Amalgamators claim that they roast Ores in order to remove the evil substances contained; they do not stop to think that if this were so, the more fire they used the more the Ores would be cleaned and purified. However, they experience the contrary, because, keeping pace with the lengthened roast, the evil substances become augmented and more avid. Thus increases the necessity of more Reagents to resist the evil effects; and the penalty is to recover from the ores neither Silver nor Quicksilver. One enemy alone does Nature oppose to Quicksilver to corrupt and destroy it, as has been said before, and that is Vitriol. Not alone is it not removed by fire from the ores, which it may be necessary to roast; rather it is multiplied and augmented; and even if it is not present in the ores when charged in the furnace, fire will produce and beget it. This is a thing easy to experiment with and see. Therefore, why marvel, when sulphide ores are roasted (augmenting more and more this enemy of Quicksilver), that greater quantities of Reagents should be needed to repair the damage? Nevertheless, had it been understood, the evil effects might have

been remedied with greater ease and less cost by washing the Ore, as I have already said, until all the Vitriol departed. A lack of this knowledge has occasioned many losses and expenses.

The other evils in themselves are not harmful to Quicksilver; solely they hinder the Silver from being incorporated with the Quicksilver and forming Amalgam, on account of the glassiness or varnishing which they produce (Sickening).

The surest rule in these Parts for judging the progress of the Roast is that the ore shall change colour, and that it should lose all of its former shine and brilliance; the said shine and brilliance, if the ores are to be treated by Amalgamation, indicate the necessity of roasting. The Pacos (Oxides) are not harmful to Quicksilver; if they contain any mixture of the above-mentioned (Sulphides) a roast is necessary.



#### CHAPTER EIGHT

THE BAD EFFECTS WHICH RESULT FROM ROASTING ORES

Even as men have proceeded up to this day without any certain knowledge of the Silver which the ores have carried, just so he has been judged to be the better Amalgamator who recovered the most from one Working producing one kind of Ore. There always remained an honest doubt if

the ore did not have more to give up.

The roasting of the black Ores and others is even vet looked on with suspicion, because there has been so little attention paid to it. There has always been fear of experimenting, because, as the saying is, it is better to play one card too little rather than one card too much. In effect this method of treatment has been considered more dangerous than advantageous. Many miracles of Nature will be observed in the roasting of ores, by him who observes with Intelligence. The Iron which they have, when burned with the Sulphur which ordinarily accompanies it, is converted into Vitriol, or Green Caparrosa (Ferrous Sulphate); this later is transmuted to fine Copper. [This is an error.— Translators.] Copper also, when roasted in the same kind of furnace, is calcined and dissolves in water like Salt; strained and evaporated over a slow fire, it solidifies to another Vitriol, or Blue Caparrosa (Copper Sulphate) like that which is called Lipes Stone. It has the admirable power of converting almost all the metals into Copper; even the purity of Silver itself will not protect it against changes of this sort. If Silver ores partaking of Alum, Caparrosa (Sulphates) and Saltpetre or nitrate-bearing Earth are calcined, the Silver breaks up and dissolves, thus

making it impossible for the Quicksilver to take it up, except through some new Artifice. Moreover, Salt alone, either begotten with Ores or mixed in the roast, is sufficient to produce the same effect, as I will show by the practical evidence of the following experiments.



#### CHAPTER NINE

EXPERIMENTS THAT PROVE THE DAMAGE FROM ROASTING ORES, UNLESS THEY ARE RECOGNIZED AND REMEDIED OPPORTUNELY

Grind a little Ore which may have Copper or Iron, and, according to the method described in Chapter Five (of this Second Book) examine for *Caparrosa* (Sulphates). Remove completely by washing. After it is dried, roast very well, throw into water again, and there will be seen much *Caparrosa* (Sulphates) newly produced by the roast. This is a common occurrence though few have stopped to give it a

thought.

And, although this Experiment should be enough to satisfy any Person, for further Proof I give another. Beat Copper or Iron into thin sheets. Grind Sulphur, and in a crucible or vitrified pot put a bed of this powder, then one of the sheets, and so on in this order with what is disposable, or what the capacity of the Vessel allows. Cover the mouth, and lute tightly. When dry, place among lighted Coals so that they surround it, but do not touch it. After a time, when the crucible is sufficiently heated, the fire should be brought nearer, and finally increased. The heat, though, should not be sufficient to melt the sheets. Take them out, and they will be found to be black and brittle. Grind finely; add ground Sulphur to the fourth part of the weight. Place in a pot-sherd, or open scorifier over the coals. Roast as when making an assay of Negrillos (Sulphide) ore, stirring constantly until the Sulphur ceases to smoke. The more times this is repeated the better it will be. Lastly, when well ground and heated, throw it into water or water upon it; at the end of a short time, decant off the water.

clean iron is put in the water it will take on the colour of Copper. [If the sheets were copper.—Translators.] Evaporate over a slow fire until a scum appears; allow to cool and it will crystallize into most beautiful and transparent green Caparrosa (Ferrous Sulphate) if the sheets were Iron, or blue (Copper Sulphate) if the sheets were Copper.

Dissolve this Caparrosa (Sulphate) or Lipes Stone in water. If a piece of Steel or Iron is put in the solution, it will go on converting itself into the finest Copper, smooth

and soft like Gold, after it has been melted.

If Lead or Tin is granulated and cast into the solution, all the surface is quickly converted to Copper; and the more frequently this is repeated the more of the Lead is transmuted, until it is all converted. The Tin is very quickly changed to Bronze. I was the first in the Province of Lipes to discover and publish these secrets. Silver also will precipitate the Copper if it is exceeding fine, and if considerable Salt is added. However, the reverse of this reaction is more to the liking of Metallurgists.

Agua Fuerte (Nitric Acid) is an ordinary substance, which, were it not so common, would be considered as having marvellous force, for it converts Silver to a liquid. It is made from Caparrosa (Copperas), Alum, and Saltpetre. The vapours which come off from these ores (?) when roasted in the furnace have the same effect on ores as Nitric Acid.

From ground Brick and Salt, especially Rock Salt, there is prepared that which is called *Cimiento* (Cementation Powder), with which Gold and Silver are parted. The Nitric Acid attracts unto itself the Gold and Silver, and alone burns them with the violence of fire. In the roasting of ores the same effect on Silver is obtained, if it is calcined in one of the ways indicated. The nitrate solution, when thrown into salt water, whitens it like Milk; it also stains the Nails and Hands when touched. These are typical effects of the solution made from Silver dissolved in nitric acid. Metallurgists should give much thought to this in order not to lose the Silver.



These inconveniences go hand in hand with the roasting of ores when there is not a competent Person to watch. Oftentimes, to overcome these difficulties, the proper way is to smelt the ores, utilizing not only the high-grade, but also the low-grade ore, as will be described in the proper place. However, not in all Parts are there the necessary factors for smelting, nor have all Ores the necessary values to support the costs thereof. The said troubles [Incidental to roasting preceding amalgamation.—*Translators*], when they occur, may be remedied as laid down in the warnings hereafter.

However, it is now possible to prepare ores so that without any Roast whatsoever they will give up their Silver by amalgamation, as will be explained in the treatise on amalgamation by cooking [Pan amalgamation.—*Translators*].

#### CHAPTER TEN

## WHETHER ORES SHOULD BE ROASTED IN CHUNKS OR CRUSHED FINELY

Ores are sometimes roasted in Chunks, and sometimes finely ground before roasting. The better practice is to have the ore finely ground, taking care to stir it uniformly in the furnace. By removing a little and mixing with Salt and Quicksilver, one may know, in a few minutes, the amount of Quicksilver necessary, how much Silver the ore carries, if the Sulphides are well reduced, if the metallic Silver is coarse or fine, and if much or little of the Reagents will be required. The roast will be continued or stopped in conformity with what the Experience of each Amalgamator has shown to him to be the best practice. In ore which has been roasted in Chunks, no uniformity of roast is found, because the force of the Fire has not been equally distributed, on account of the unevenness of the bed, and the size of the Stones. It is clear that the smaller pieces are roasted before the larger ones, and that those in the middle of the furnace and in the centre of the Fire are roasted before those on the sides. However, in roasting in chunks there is less likelihood of over-roasting, and there is the added advantage that the coarse-roasted ore is more easily ground.

Much in error is he who roasts finely ground ore in a Reverberatory. So strong is the fire that all the Sulphur or Pitch which the ore contains, instead of being dissipated slowly, mixes with the Silver, and all is lost as Slag. Furthermore, the draft will lift up the fine Silver when the charge is stirred and, entangled in the Smoke, it will be carried out of the furnace. A Muffle Roast is the safest for ground ore; the kind of furnace adapted thereto will be described here-

after. Finely-ground ore may ball up, and even if this does not happen, it will at times become a spongy mass, and somewhat lumpy, because of the Fire; wherefore it is best to regrind before making up the amalgamation charge.

The surest way is to roast the ore in chunks, which will facilitate, as has been said, and also shorten, the grinding. Thus ceases the loss of the fine Silver going off in the smoke. It is best that the hard Quartz ores, which it may be necessary to roast, and which are less juicy [Lower in sulphur.—Translators] should be so treated. Others [Massive sulphides.—Translators] should not be roasted alone, but finely ground and mixed with other ores, according to their deficiencies, as will be explained.



#### CHAPTER ELEVEN

#### THE THINGS ONE MUST MIX WITH ORES TO ROAST THEM

Not an extraordinary thing, but very common, is the begetting of Iron jointly with Gold and Silver ores. Those ores which partake of Iron are the most rebellious in roasting and the most difficult to smelt; the slowness with which heat penetrates the iron ore has already been commented on. If a piece of *Piedra Iman* (Magnetic Iron Ore) is passed over the very well roasted and ground ore, there is lifted up more or less, according to the abundance of Iron the ore contains. This class of ore, after it has been well ground, should be mixed with Sulphur, or better, with ores which may have Sulphur. Ground Antimony also, in the proportion which the quantity of Iron may require, is mixed with the ore and muffle-roasted slowly, until, when a small portion is taken out and tested as usual, it is found to be well conditioned.

Sulphur is the Destroyer of Metal, from whose influence only the perfection of Gold exempts it. Tin is offended the least, and Iron the most, by Sulphur. This is the reason why, when these two opposed substances come in contact in the furnaces in which they are roasted or smelted, they become mutually destructive and leave the Silver free. In the same way may be cured those ores which have Sulphur or Antimony, by mixing and roasting them with Iron ores or slag.

Those ores which contain Orpiment or Dragon's Blood are roasted with Soroches (Galena). Those which have black or white Pitch [Carbonaceous matter.—Translators] are roasted with slag of Iron, and finely ground white Stone, from which Lime is burned.



In addition to the method indicated above, one may recognize the mixtures in ores by the colours of the Smoke which comes off when a little coarsely ground ore is placed on a well-heated iron plate. If the smoke is White or Black the ore contains Pitches of those colours. If it is Yellow, it has Orpiment; if red, Dragon's Blood; if in the centre it is Yellow, with the edges Green, it has Sulphur. Nevertheless, the Earths mined with ores at times give off in their smoke similar colours.

#### CHAPTER TWELVE

## WHAT THE AMALGAMATOR SHOULD DO BEFORE MIXING THE CHARGE

Duly appreciating all the aforesaid (although the Sorting does not come within his province), having ground and screened the Ore to the necessary fineness, and with the intelligence demanded, before he starts to make up the charge or roast the Ore (should there be necessity), the Amalgamator should make an Assay in the following manner: Set apart three or four pounds of Ore finely ground and freshly mixed. On a small quantity make two Fire-assays in the manner to be explained later on; there will then be known to a certainty the Silver which the charge contains, and what should be recovered; or, we may suppose for a beginning that the ore is a pure Paco [Oxide, gossan.— Translators] not needing a roast. If it contains Copperas or Blue Vitriol they should be removed, as has been said before. Test one pound by amalgamation, using the least Water possible; allow to settle a little. If there arises to the top a cream-like Scum, which is the grease or Unctuousness of the ore, it should be drained off and washed as much as necessary with clean water, to remove this disturber. Pour off the superfluous water; throw in Salt and Quicksilver, and, using no other reagent, proceed with the amalgamation. Always take note of the condition of the Quicksilver; whether it runs together well; whether it picks up the Silver well; if it flours or if it fails to amalgamate. the Ouicksilver begins to disappear it is a sign that the Ore is taking it up. Continue the amalgamation until it can be seen whether the attraction of the Silver and the continued workings have spent the Quicksilver; this only happens

when the treatment is excellent. Continue until the Silver shows up like very fine Filings. When Quicksilver is no longer taken up, wash the test, and the recovery based on the Fire-assay can thereby be determined. The ores of Berenguela de Pacajes are like to the aforesaid, and in the beginning many ducats were lost there on account of amalgamation with many reagents, as these ores were thought to be impossible of treatment otherwise. To-day they are treated with only Salt and Quicksilver, and they yield up in this way even as they would in smelting, that is, all the Silver contained. These ores are of the sort that bear Copper.

If the test shows "Lead" (for it is thus they call it), that is, if the Quicksilver loses its lively colour [Is sick.— *Translators*], and assumes a look of Lead, there is need of some material to clean it, so that it will the better embrace and recover the Silver.

The materials possessing this Virtue are finely divided Iron, Lead, Tin and Quicklime; Ashes also have a like effect. Any ore whatsoever may be treated with any of these materials, although, for the reason of natural Convenience and Concord, it is more appropriate to use the substance which is more symbolical of the ore mixture. If the floured Quicksilver is very dark and inclined to Black, Iron is more appropriate; if lead-coloured, Lead; if lighter still, Tin. To golden Quicksilver (so coloured by Copper) should be added Lime. Little by little, by count and measure, there will be added the reagents necessary, until the Quicksilver remains clean and takes up the Silver. The quantities necessary to add to the full scale charge can then be calculated according to the weight to be amalgamated.

If the Quicksilver becomes floured, and this has not been caused by excessive grinding in the amalgamation, then the cause of the flouring proceeds from the Baseness of the Ores, a typical trouble with Galena and Pyrite, and the other shining Ores; therefore it is necessary to roast them, as has been said before. Rocks without Silver content may



cause the same trouble to Quicksilver, and, although the Quicksilver may be cut up into a fine white powder, if the material treated is neither raw Black Ores nor Pyrite, there will have been no Silver in the ore tested, and no attention

need be paid to it.

If the Quicksilver remains clear and runs together well in the preliminary test, and continues to take up the Silver, there is no necessity of other reagents. All tests should be started with only a little Quicksilver, in order that it may be added as convenient. If possible, add an Excess, because the treatment is then surer and shorter, as will be explained later. Furthermore the Amalgamator should leave nothing undone until the small-scale amalgamation test corresponds in recovery to the Fire-assay result. According to the result attained, he will proceed in the treatment of full-scale charges.



#### CHAPTER THIRTEEN

THE WARNINGS OF THE LAST CHAPTER IN REGARD TO ROASTING ORES ARE CONTINUED

If the ore should of a necessity have to be roasted, in conformity with that which has gone before (after the Fireassays have been made, and the Silver content is known) the Amalgamator will do so, heeding the Warnings aforesaid in regard to the mixture and quantity to be treated, and taking into account the facilities there are for work. Ores should not be roasted with Salt, because, while it aids in the calcination of the Silver, it penetrates the ore, thus harming the Silver. [Loss by volatilization as silver chloride.—

Translators.]

One cannot fix precisely the number of Hours the ores should be roasted, although it is a sure rule that they are sufficiently roasted when, upon a little of the pulp being tested, the Quicksilver remains in globules, stays bright and takes up Silver. This effect is never in doubt if the firing is persevered with, and the ores are roasted with the right mixture and in the correct quantity. These factors, as in the case of *Pacos* (Oxides), will be determined by small-scale tests, by which one may know how much material (reagents) has to go into the furnace with each charge of ore. However, as there are but few times when one adjusts himself to these Instructions as he should, it is well to keep in mind the following Warnings:

When ores of Sulphur and Antimony are undergoing a roast and cease to give off bad Odours, it is a sign that the Sulphur and Antimony are driven off.

Those ores which abound in carbonaceous matter will, at the beginning of the roast, give off a thick black Smoke, which, by getting thinner and whiter, is a sign that this

Inconvenience has been disposed of.

The changing of Colour by an ore, the loss of the Lustre which it had before roasting, and the turning from Negrillo (Sulphide) to Paco (Oxide) is a most certain sign that the ore is well disposed towards Quicksilver, although there is a very great latitude in this.

The ores which contain Copperas (Sulphates), if they must be roasted, are cleaned of it first by washing the ground ore, as has been said before. Ores that contain Copperas when charged into the furnace remain highly coloured after roasting; he who roasts Copperas alone will see this

change of colour with his own eyes.

On testing a little of the pulp, if the Quicksilver commences to foul, it is a sign that, with the heat, the Copper and Iron contained in the ores, mixed with Sulphur (also a companion of Antimony and Pyrite) are being converted into Copperas. The longer the roast the more Copperas.

When the charge is removed from the furnace, a pound, or as much as one may desire, is set apart. Water is poured on it to a depth equal to the thickness of three or four Stir slightly and allow to settle at once. If the water turns white, or stains the Nails or changes the colour of a tape when put into it, it is a sign that the Silver has been calcined (made soluble) and that it will break down and be dissolved in water like Salt. Put this water in some vitrified vessel and wash the ore two or three times until the wash water is no longer cloudy and all the Silver which may have been calcined is gotten out. Evaporate over a slow fire, and all the Silver will be recovered, and may be utilized by melting the residue. If the water into which the hot ore was thrown does not give signs of having soluble Silver, put a little clean Iron in it. If it takes the colour of Copper, it contains much Copperas (Copper Sulphate). Wash the ore as indicated, until the Copperas is eliminated and the Iron is no longer stained. Save the Waters, as they may later be utilized in the treatment of ores which need



Copperas. Now, if it be evaporated and the residue be melted, there will be obtained fine Copper, and the residue may contain some Silver, if any has been made soluble in the roast.

Test on a small scale, by amalgamation, the ore thus conditioned, in the same way as was described for *Paco* (Oxides). Continue this testing until the experiments made show how the full-scale treatment can be carried out well enough to obtain all the Silver that the fire assay indicates. Judge none of these Experiments as partaking of unnecessary and prolix Curiosity, because there is in this matter of ore treatment nothing more important and beneficial [Than the preliminary tests.—*Translators*], though nothing more commonly ignored. After a few days of care and work, the amalgamator will recognize the kinds and qualities of the Ores he handles, and will know how to proceed with them, without repeating the Annoyances of so many tests.

But, with all the aforesaid, the ore never arrives at the stage of being perfectly conditioned, so long as the little or much Silver contained is not purified and brightened in the pulp, before charging the Quicksilver. It is not possible to bring it to this state, because ores with a little Lead may be reduced through the roasting alone, while the Black Ores, and others, through their Sulphur fumes will film the Silver also, although this latter is only arrived at by prolonged roasting. In one way or another, by cookings and working over with reagents such as Alum, Salt and other substances, Silver may be cleaned and brightened. The ore being in this condition, Quicksilver needs no added reagent, and not more than four days will be needed to recover all the Silver. Moreover, there will be but little consumption of Quicksilver, because of the short period of treatment and the lack of excessive mixing and working over of the charge, which breaks up and flours the Mercury; this flouring is the principal reason for loss of quicksilver, as will be seen shortly.



## CHAPTER FOURTEEN

## THE NATURE OF QUICKSILVER

Leaving for another Occasion (which perhaps Time will grant) the more detailed description of Quicksilver and some common but useful Experiments therewith, I shall, for the present, touch but lightly on this Phoenix of the Sciences. Raymond, in his "Intellectual Art," followed by all the believers of the occult Philosophy of ores, thought that Nature created this body out of a substance so uniform, and of parts so perfectly united, that not even Fire, its greatest opponent (as is vulgarly imagined), has power to divide, corrupt and destroy Quicksilver, as it visibly is able to do with ores and other bodies of the World, aside from Gold and Silver. Quicksilver will be proof against Fire if it is given the proper conditions, which have been discovered by several Persons, and some known by me. Or, with the Fire, it will flee as a sort of Vapour, which, encountering some body to cool it, will be condensed again to its original form, without the least loss of its former weight. Not even the Evil Substances, mentioned before as ordinarily occurring with the Ores in their Veins and with the amalgamation charges, can corrupt Quicksilver permanently. Although Copperas, when sublimed with Quicksilver and Salt, may flour the Quicksilver in such a way as to seem to consume and totally destroy it, by converting it into another substance which we call Solimán (Corrosive Sublimate), this destruction does not in reality take place. All these accidents have a Remedy, and it is not impossible, nor even very difficult, to revive and reunite the floured Quicksilver. The manner of doing this will be shown in its proper place.

#### CHAPTER FIFTEEN

WHICH TREATS OF THAT SUBSTANCE CALLED LIS [FLOURED QUICKSILVER.—TRANSLATORS] AND OF THE DIFFERENT KINDS THEREOF

Broken up and very finely divided Quicksilver is commonly called Lis by amalgamators. It is seen as a fringe in the horn-spoon when ore is being tested; and from it experienced amalgamators obtain an indication of the quality of the Ore and the condition of the charges being amalgamated. Flouring is caused by too long grinding of Quicksilver with the charge (a thing inexcusable in ordinary treatment), even if the ores contain no Evil Substance whatsoever. Of the Evil Substances, Copperas (as has been said) flours Quicksilver to a very great extent.

When Quicksilver has not been affected by any foreign substance, but is simply broken down to a white flour, it is called *Lis* of Quicksilver; the floured Quicksilver made in grinding with Tin and Lead ores is called *Lis* of the corresponding metal. *Lis* of Silver is very finely ground Silver which, although it is covered with Quicksilver is not yet so thoroughly amalgamated as to form what is called *Pella* 

(Amalgam).

Quicksilver takes unto itself various Colours, and they are shown in the *Lises* (the floured Quicksilver) according to the different things which accompany the Silver ores into which it is charged. These can be reduced to three classes, which embrace several subdivisions, the three classes being Clear, Leady and Fouled. Quicksilver shows Clear either when the ore has no Silver, or when the Silver which the ore contains is of the purest, without any interfering element, or mixture of Base Metal. In this case the Quicksilver will take up and absorb the Silver without losing its lively colour.

When the colour becomes leady, and the ore continues to give indication of some Silver, unless the amalgam film is false, it is due to certain causes and principles. These have been given but little consideration in amalgamation, in which, up to this time, there has been much of the haphazard.

Copperas alone, the Arch-enemy of Quicksilver, gives the colour which is called Plomo Falso [False amalgam film.-Translators]. Like other ores, those of Copper also carry Copperas. [Note that Barba uses Caparrosa to mean either iron or copper sulphate.—Translators.] The other Leadcoloured films are a certain sign of Silver, because ordinarily it is begotten in crude ores and mixed with others of a baser sort. The Quicksilver, attracting unto itself the Silver, carries along at the same time the accompanying mixed metals which give the unusual Colour. This is the foundation for the previous statement in Chapter Twelve of this Book, and the Reason by which one knows that the dark, inclining to Black, Colour of the floured Quicksilver, or Quicksilver itself, proceeds from the admixed Iron. If the Quicksilver flour, or Quicksilver itself, is Lead-coloured, it is accompanied by Lead. If it is somewhat more clear, by Tin, and if inclined to be golden it is accompanied by Copper.

Whether the flouring is due to foul Quicksilver, Base Metal, or Silver is easily recognized. The flour of Quicksilver alone shows itself as very fine, white and without life; on washing down the pulp in the horn-spoon, the Quicksilver does not run, but remains behind as though it were stuck to the bottom; if it is stirred up with the finger it will run together in Grains of lively Quicksilver. Floured Silver amalgam shines like Filings, coarse or fine, according to the richness of the ore; it runs or rolls on the bottom of the horn-spoon behind the sand; stirred up with the finger, it consolidates into an amalgam ball. The floured amalgam of Base Metal may be between the two; when consolidated through stirring, it resembles fouled Quicksilver.



### CHAPTER SIXTEEN

WHETHER ALL THE QUICKSILVER AND ORE SHOULD BE CHARGED TOGETHER

Having duly conditioned the ore, ascertained the Silver content of the charge, and the quality and quantity of the Reagents and Quicksilver needed, the amalgamator may still be in doubt whether he should put all the Quicksilver and Reagents at once into the Charge, in order to secure the suitable proportion of three parts of Amalgam to one of Quicksilver when he makes the clean-up. It is the opinion of some that it is best to throw all the Quicksilver into the charge at the beginning, and everyone followed this practice up to twenty Years ago. At that time I went to the Province of Los Lipes, where I used, and persuaded others to use, a different practice, being influenced thereto by smiliar work of Raymond which clearly concorded with Common Sense.

Little by little, softly and without haste or violence, all things grow and are perfected. A little Fire is enough to heat the whole World, if the fuel is applied little by little, according to its heat-giving power; but if, at the beginning, all the wood is piled on, the Fire will be smothered and quenched. The natural body-heat of Animals is subject to the same inconveniences, and proportionally the same thing happens in the treatment of amalgamation charges, because whatever may accidentally cool will slow down the Treatment, and whatever may cause heat will hasten it. In addition to this, if the charge has not been handled well (and approximately as the Ores require) it may be lost and the Quicksilver floured. The thicker the Charge the easier the remedy; if the Charge has to be brought back with Tin

or Lead (which must be used as amalgams.—Translators), the thicker charge allows it to be done with less risk. Equal or greater slowing down and damage will follow if an Excess of reagents is added to the ores which may need them. Through this Excess the Quicksilver may be sickened and may take up no Silver whatsoever; with difficulty only can the charge then be brought back to the necessary condi-

tion, after many expensive delays and doctorings.

Therefore, mix with the Charge only one-third of the total Quicksilver [which the small scale test has shown to be needed.—Translators], and, at the beginning only one-half of the Tin and Lead amalgam which may be needed. In this way the Quicksilver will take up the Silver quickly, and it can soon be recovered before all the reagents are spent: this happening is called "Loading-up." By thus hastening the amalgamation, one may avoid the loss of Silver due to dry Amalgam being floated up in the pulp, occasioning great loss. Continue to add Quicksilver and Base Metal amalgam to the Charge, as it may be needed, but diminishing them proportionally, so that the amalgam is at no time wet. In this way there is not much flouring, and the amalgam itself is an element in the recovery of the rest of the Silver, making the treatment surer and shorter.

If the ore has to be treated with Lime, the rule for using reagents does not hold good. In the case of amalgamation with Lime, put in all the charge at once, and work over very well two or three days before adding the Quicksilver, being very careful not to have an Excess of this material, because Quicksilver, if it has unnecessarily been contaminated, with difficulty takes up Silver, and is harder to recover from the

charges.



### CHAPTER SEVENTEEN

THE WORKING OVER OF THE CHARGES AND THE EFFECTS
THEREFROM

The first and principal Object of working over the Charge is to distribute the Quicksilver in the ore so that all particles of it may pick up Silver. Also, the Heat caused by moving the Charge tends to put it in better condition. Lastly, by the Friction the Silver is purified and cleaned: this is called "Grinding-in." The working over is a most necessary and important part of all ordinary Amalgamation practice; nevertheless, there have resulted many millions of inexcusable loss in Quicksilver consumption, due to excessive grinding when amalgamating. The Quicksilver is squeezed to such an extent between the fine and coarse Sand that it is divided into very fine particles (being then called Lis); in this condition, remaining as it does without weight or body, when the Charge is washed it does not go to the bottom of the clean-up tub. Instead, it is drowned to such an extent, and mixed with the slimes, that it flows off with the wash water. This damage can be prevented, to a great extent, by two Precautions. To begin with, the first and second day, there should only be two gentle Grindings, so that the Quicksilver is disseminated but not floured, because before the Silver amalgam begins to form the Quicksilver is more disposed to break up unduly. The Second Precaution is always to carry on the amalgamation so as to have the Amalgam dry, and not with an excess of Quicksilver or wet Amalgam. Add the Quicksilver little by little as may be necessary, and in this way, the Quicksilver and dry amalgam will be, at the most, in the Proportion of one of the former to two of the latter. Nor should any one deceive himself by thinking that when there is an excess of Silver, and so long as there is a sufficient quantity of the reagents, the trouble will not happen. It may even come to pass that there will be a greater Loss through flouring due to excessive grinding, and the possibility of consuming all the reagents; then there will remain behind only the Quicksilver, floured and sickened by the reagents themselves. On further grinding, this sickened amalgam is only lost. With finely-divided Silver there is not this risk, because the grindings do not waste nor consume it, but rather purify it more, so that it the better embraces and is united with the Quicksilver.



### CHAPTER EIGHTEEN

MISHAPS WHICH MAY OCCUR IN AMALGAMATION, AND THEIR REMEDIES

Various are the Accidents which may happen to the charges in the course of amalgamation. The subject of all of them is the Quicksilver which alone we take into account, because it, as a Mirror, reflects the good or bad condition of the charge. The charge in itself, owing to the fineness of the Sand to which it has been reduced, and the mixture of the Earth with which the Silver was begotten, is not so easily judged by a visual examination. If the Quicksilver is very much sickened, owing to the presence of an excess of such reagents as Lead, Tin, Iron or Lime, the globules will be flattened, or even elongated and like unto a Worm, instead of being round. If shaken around in the horn-spoon without water, the sickened globules will tail out and stick to the spoon. In this condition its Activity is lessened and the recovery of the Silver is impeded. By the force of much working over, this Damage can be remedied, but at much cost and loss of time. The quickest and most efficacious remedy is Copper Sulphate, or that solution thereof which I advised, in Chapter Thirteen of this treatise, should be recovered and set aside.

Add Copper Sulphate water to the charges when they are reworked, more or less, according to the fouling of the Quicksilver, and the almost instantaneous Effect will be noted. The Reason is clear: as has been stated, Copper Sulphate dissolved in water, visibly and truly converts the base metals into Copper. And it is thus that they lose the Coldness which they formerly had, and which slowed up the Quicksilver, and take upon them the Heat which is a

property of Copper and is the cause of the Quicksilver being livened up. On this is founded the beneficial effect of ground Copper when put in the charge. Here it is to be noted that not all the ores of Copper, nor even the rich ores, are appropriate for cleaning up or making the Quicksilver fit for amalgamation; solely those which abound in Verdigris or sulphate are usable. The Virtue encountered in the so-called *Magistrales*, used for their effect in heating and cleaning amalgamation charges, is due to the same Copper Sulphate, produced, as before mentioned, in the roasting. For the satisfaction of those who may desire to know, here are set down the composition of some of the *Magistrales*:

Roast Copper ore, and after it is ground and kneaded with an equal quantity of Salt, make into Bricks and roast again.

Another: To two parts of Copper ore add one part of Salt, and no more; knead together and roast. To one hundred pounds of this powder add eight ounces of Brass filings.

Another Magistral is made from slimes, sand tailings and salt, by third parts, well roasted.

Another from Copper ore, sand tailings and salt by third parts, all well roasted.

Another can be made from sand tailings of the ore being treated, and salt, equal parts [To be roasted?—Translators].

Another may be prepared from Copper ore, sand tailings, some of the ore to be treated, finely ground, Iron slag, and salt, equal parts all kneaded together, made into Bricks and roasted.

Another is made from three parts of roasted slimes and one of salt. However, everyone invents such Mixtures and proportions them in his own fashion, and as he finds best. The foundation of all *Magistrales*, as has been said, is Copper Sulphate, produced in the roasting. This may be seen by anyone who will follow the Instructions given, and the result seems to confirm Pliny's statement, that Copper was begotten by roasted Stones. One should use these *Magis*-



trales with the same circumspection as the other reagents mentioned. Before mixing up the charge, preliminary tests must be made to ascertain the proportional amount of reagents to be added; because if there is an excess of reagents there arises another dangerous condition, described as follows:



### CHAPTER NINETEEN

WHICH CONTINUES WITH THE SUBJECT OF THE LAST CHAPTER

An accident opposed to that mentioned in the last Chapter, and which is a source of great Quicksilver loss, is excessive Flouring, that is to say, the condition in which no Amalgam forms. Greater still is the damage if this excessive Flouring is due to Copper Sulphate, as there will then be much scattered Quicksilver in very round and lively Particles which keep separate from the amalgam. These particles do not become elongated if divided; rather all parts assume spherical forms, although very small. One remedies this trouble with contrary reagents, which will, as said before, liven the Quicksilver. Iron has this particular virtue, attraction and natural sympathy, and is most appropriate to reunite and give body to the scattered and almost corrupted Quicksilver. The manner of using it will be treated more fully hereafter, when the washing of the charge [Cleanup.—Translators] is considered.

No certain rule can be given in regard to the quantity of reagents to be used to correct charges which have gone off, because neither the effects nor the causes are always the same. However, it is better, in general, not to work over the charge until the Amalgamator has ascertained from small scale tests what is necessary. Set apart at once a third or fourth part of the charge, and in it alone charge all the reagents and work over until they are very well divided and incorporated. This part will then be mixed and well worked over with the rest. In this way the reagents will be better and more uniformly mixed, especially if the quantity to be added is small. Be careful to follow the treatment

found necessary, so as not to give place, Firstly, to undue fouling of the Quicksilver; Secondly, when remedying the fouling, do not add such an excess of Copper Sulphate as to

flour the Quicksilver.

If, on testing the charge with the horn-spoon, it is found that the Quicksilver is in little Globules, or divided into Grains, and will not unite, it is a sign that the amalgamation is not coming on well. That which is like a Shell or Film around the Globules of Quicksilver does not permit them to unite. The lack of reagents alone may cause this. Sometimes the condition can be remedied by adding Base Metal amalgam, or roasted Tailings (which by their acidity aid in cleaning the Quicksilver), or by continued Grinding.

Some throw in Ashes, but the true and natural remedy is Salt, and that substance called *Millo* or Alum, used to brighten Silver. There is ordinarily an abundance of this in mining Districts. It is not lacking here, in Potosí, in Guaco de Santiago, an *Arroyo* where this alum water

continually flows.

When the charges are not uniformly worked over, or the Quicksilver is not added when necessary, or when the pieces of amalgam fail to go together, the amalgam is said to be dry. In the tests with the horn-spoon it will be found in curly pieces, and if the trouble is not remedied before the charge is washed, the amalgam will remain in the charge and go off with the slimes, with great loss to the owner of the ore. It is not wise to try to recover dry and floured amalgam until the charge is ready to clean up; it can then be done by adding an excess of Quicksilver. Wet silver amalgam is also very good, if added to the charge and worked in just before the clean-up.



### CHAPTER TWENTY

HOW TO DETERMINE WHEN THE CHARGE IS READY FOR THE CLEAN-UP

There is no fixed Period after which the charges should be washed, or cleaned up. Their ripening is hastened by too much Grinding, the exterior heat of the Climate or Weather, and the interior heat derived from the Copper, or Copper Sulphate, and other substances which partake of their virtues in cleaning and purifying the Silver. The roasting of the ores is also an important factor. On the contrary, the treatment will be prolonged if the number of workings over are not sufficient; and the same thing happens if it is freezing Weather, if the charge is overworked, or if the Ouicksilver does not keep bright. One arrives finally (after overcoming these and other Troubles) at the point of taking out the clean Silver mixed with Quicksilver; the operation of separating it from that which is earth is called Washing. Not a little Knowledge is necessary to be able to tell when this stage has been reached; because, if it be not reached, one loses the Silver which has not yet been amalgamated. If the treatment is prolonged, the amalgam is ground up, and even if this is not carried too far, there is at least the loss of time and Silver due to excessive grinding, in addition to other risks.

Subject to many grave Errors have been the rules employed up to the present for determining if the charge is ready to wash; if it is in good condition; if more Quick-silver is to be added; when the Silver has all been amalgamated; and whether the mass of Quicksilver and Silver is clean, and of a colour which inclines as much as possible to that of Gold. There are many other Troubles to be

watched for, all of which may cause further mishap. The infallible and certain Rule is to determine if the Quicksilver has taken up all the Silver which the fire assay, made at the beginning, showed the charge to contain. If this result has not been attained, halt the work, but do not wash the charge. Further small-scale amalgamation tests should then be made on the charge, and from the experiments one will recognize the trouble or what is lacking, and thus the remedy may be applied and the final point arrived at. Being ready to wash, the amalgam being dry and in the aforesaid proportion of Quicksilver and amalgam, some fresh Quicksilver should be charged and worked over gently two or three times. In this way the charge should go to the tub with a proportion of three parts of Amalgam to two parts of Quicksilver; or, at least one of Quicksilver and two of Amalgam; thus, some of the floured Quicksilver, as well as unamalgamated Silver, will be recovered, and the greater volume of Amalgam will sink the more readily in the cleanup tub, obviating the loss from suspended Amalgam. When the clean-up is begun, charge some fresh Quicksilver into the vessel called a clean-up tub. Stir well into the Ouicksilver and Amalgam of the charge; this will help the recovery, and the more there is added the lower the loss of dry amalgam flake.



### CHAPTER TWENTY-ONE

WHICH SHOWS THAT IN WASHING THE CHARGES ONE CAUSES A LOSS OF QUICKSILVER

All the troubles which have been experienced, and are experienced to-day, through what is called Consumption and Shortage of Quicksilver, take place in the clean-up. Up to this point there is nothing lost, and one's Sight deceives if he judges otherwise, even on the occasions which have arisen, and may again arise, when neither Quicksilver nor Amalgam is recovered from the ore with which it was mixed. Not only are these accidents which alter, but do not corrupt or cause loss of body to the Quicksilver; in the charge, even when it is in more or less good condition, the Quicksilver may to go out imperceptibly with the Water and Slimes. The immediate cause of this damage is the excessive Fineness, and (one may almost say) lack of body and weight, without which the floured Quicksilver will not sink to the bottom of the charge. Rather, on washing, because of the stirring, the floured Quicksilver is entangled and flows off in the slimy water. Afterward there is a shortage of the Quicksilver originally charged, conforming more or less to the greater or lesser grinding and abundance of floured Quicksilver.

Grossly have they erred who, self-persuaded, believe that, in the amalgamation of Ore, Quicksilver is truly consumed, holding as sufficient proof, and the strongest reason for their belief, their Experience in ore treatment over many years in this Kingdom. Here the best trained of amalgamators has consumed as much Quicksilver as the Silver he has recovered; and he has not perceived that he is deceived by the very things his hands touch. The missing Quicksilver

and amalgam remain in the Sands and Slimes, as the owners of the ores know to their sorrow. Of frequent occurrence in these Provinces are the fortunate Discoveries of those

who buy Tailings.

Others, speaking as Philosophers, attribute the consumption to a Debility which appears in the Quicksilver when it is occupied in attracting Silver, as happens with other things in Nature. They would have proven something if, at the same time, they had shown that Contrariness of Qualities, which would be necessary for this reaction between Quicksilver, Silver and like Metals. It is the aim of all these to attribute, not only to Silver, but to the accompanying ores as well, this opposing quality which destroys Quicksilver. However, they can neither prove the cause, nor show to be true the imagined Consumption of Quicksilver due to this so-called Debility. Such does not exist, and definite experience proves the contrary. The most completely lost and broken-down charge can be brought back, and all Quicksilver recovered, by the method which will be explained hereafter.



### CHAPTER TWENTY-TWO

THE LOSS OF QUICKSILVER AND THE REMEDIES THEREFOR

The grinding together of the charge and Quicksilver is one of the lesser causes of the losses of Quicksilver, because of the squeezing and dividing action, resulting in particles called Flour. With whatsoever Ore, Earth or Sand the Quicksilver is charged and ground, there will be the said effect, greater with the Galenas, Pyrite, and Steel-coloured ores, which, by their weight and glassiness (for it is thus we call it) more easily cut and break up the Quicksilver.

Copper Sulphate, by its nature, as has been said at various times, aids violently in this breaking up of the Quicksilver, and has been the cause of the greater part of

the losses.

Among the contributing causes of Quicksilver loss is Salt, used in amalgamation and the clean-up, because, as all know, it increases the density of the Water, so that not only the floured Quicksilver of but little Weight, but even things of greater Weight may be suspended, and not go to the bottom.

The Slimes, which are mixed in this Water and make it turbid, increase the density, and more easily suspend the Quicksilver, allowing it to go off and be lost therewith.

And lastly, there is the movement of the stirrer during the washing, which also prevents the floured Quicksilver from sinking, thus augmenting the aforesaid Evils by its inclination to keep the particles suspended. This is certain and patent to all.

The ordinary grinding in this class of treatment cannot be eliminated, but, if the aforesaid Warnings are heeded, it will be less harmful. Also there has been shown a way to remove Copper Sulphate from ores, and to overcome the refractory character of Pyrite, Galena and the Steel-coloured ores.

Salt may be recovered from the charges with two advantages: the lessening of Quicksilver loss, and the saving of this reagent, for which a great many ducats are spent annually. Treat the ore in Boxes, of the type ordinarily used, closed on all four sides. Let the bottom slope slightly, but no more than necessary, so that the water will run to a common point. At this point let there be a Hole, ordinarily closed, through which at the proper time the water can be let out. When the charge is to be washed, run on water in abundance, and open up the pulp in many places with a Hoe to secure a better penetration of the water. At the end of a short period of this mixing, open the hole and allow the water to escape, carrying with it no small part of the Salt contained in the charge. Save this Liquor in a suitable vessel, where it may either be allowed to crystallize, or it may serve again for treating charges. Wash two or three times, until the water which comes off no longer has the taste of Salt.

If the charge has to be washed three times, it is better to wash it six times, whereby the water will be less slimy and twice as easily clarified.

The stirrer should not always be kept in the same position, because, if this be done, the fine particles of Quicksilver or unamalgamated Silver will always move in parallel Circles, at equal distances; they will not come together, nor will they unite, the one with the other, to make more body and thus sink to the bottom. At every fourth or sixth Revolution the stirrer should be shifted a certain amount. However, as this cannot be done in the ordinary clean-up tub, insert a Baffle, which will oppose the movement caused by the stirrer, thus disturbing the Course followed by the floured Quicksilver and unamalgamated Silver, causing them to find one another and become united. The stirrer and all the tub (except the bottom, which does not need it on account of the Quicksilver



bath) is covered with amalgamated sheets of Copper or Iron. In this way whatsoever part of floured Quicksilver may come against the sheets will stick and be held there. On washing the charge, the Quicksilver and Amalgam are easily removed and scraped together with a piece of sole-leather, felt or cloth.



### CHAPTER TWENTY-THREE

## SQUEEZING AND RETORTING THE AMALGAM

After the Quicksilver and Amalgam are taken out of the tub, they are squeezed in a double cloth, wetted in warm water, in order to remove the excess Quicksilver. One may assist this removal by blows from Paddles, so that as much Quicksilver as possible may be separated from the Silver. Put the amalgam into the customary Moulds, which, because of their pyramidal Shape are called *Piñas* 

(Pine Apples).

The Silver yield is approximately one-fifth of the amalgam. For example: from one hundred pounds of amalgam there will be obtained forty marks (three hundred and twenty ounces) of Silver. The yield of Silver in amalgam of rich ores is inclined to be less than in that of poor ores, because the Silver of the former is more spongy, and the Silver of the latter finer and denser. Even when the greatest care is taken, some of the Silver amalgam passes the cloth when it is squeezed. The wetter the amalgam the more of it will pass.

In the case of water mixed with mud one sees a similar thing. Even with the greatest care in pouring off the water, it will not continue to be clear and pure, but will be made turbid by the mixture of Slimes it carries. The more water poured off, the more the mud with it. Allowed to rest and settle, the mud assumes body and separates from the clear water. The same thing happens to Quicksilver which has been squeezed out of amalgam and left to settle in the boxes or tubs. At the end of some days a quantity of Silver amalgam settles out. I myself saw in the Santa Catalina Ingenio (Mill), in Los Lipes, a considerable quantity of amalgam recovered from the bottom of a Quicksilver tank.

If the Quicksilver is heated, more of the amalgam, and therefore more of the Silver, will pass through on squeezing. For this reason, when the hot amalgam from pan amalgamation is squeezed, even with much care, Silver will pass through the cloth. If the Quicksilver is strained again the following day, after cooling and setting, additional amalgam will be obtained.

Very great, and without any Excuse whatsoever, has been the loss of Quicksilver in retorting. Notwithstanding the low cost of treating ores to-day in this Imperial Village, the yearly retorting loss alone amounts to at least 30,000 Pesos. Thus can be conjectured the sum that has been lost in the amalgamation of the rich and abundant ores of this and other mining camps of the Kingdom. This loss proceeded (and still proceeds) from the lack of care in selecting the Material from which the pipes and retorts are made, as well as from the little diligence that is used in luting the retorts and condensers. The Clay from which they are commonly made is very spongy and full of pores, so that water will pass through and sweat out on them. Thus it is no marvel that the Quicksilver, converted into a dense vapour (and in a fine state of division due to the Fire, which has also expanded the pores of the retort), penetrates the vessels and is lost.

To say that some part of the Quicksilver itself is corrupted by the force of the Fire is purely the Imagination of those who have little Knowledge of the uniformity of this substance, as said before. Make the retorts and pipes from that clay used for crucibles, and the trouble will cease. The retort thus made will be a lasting work, owing to the quantity it will condense and the way it will resist the fire. If by mischance it should receive a strong Blow, it will not break.

In that noted village of San Felipe de Austria de Oruro (Oruro of to-day) famous for the Gold and Silver veins which enrich it, there is a vein of White Earth, in a small hill above the Church of the *Rancheria*. From this vein is obtained a



Clay so tough and dense that, after burning, it is not surpassed by the finest of China-ware. I experimented with and publicly advocated the use of this for Crucibles, with no small benefit to those who had need of them. Up to the present, because of the little Time at my disposal and my many Tasks, I have not been able to find a similar Clay in this Village (Potosí), but I do not doubt that it exists. Potosí, in her abundance of the Riches of Nature, has never lacked the means to augment the Splendour and Renown of her ores.

But, when and where good Clay is lacking, mix the best attainable with Iron scale or Slag finely ground. Pug the Clay well and make the retort. Burn it very carefully, and it will be found to serve with less risk of damage than those ordinarily used. It will be well to vitrify the inside of the pipes, but the retort should not be vitrified, because the violence of the heat will crack off or fuse the glaze.



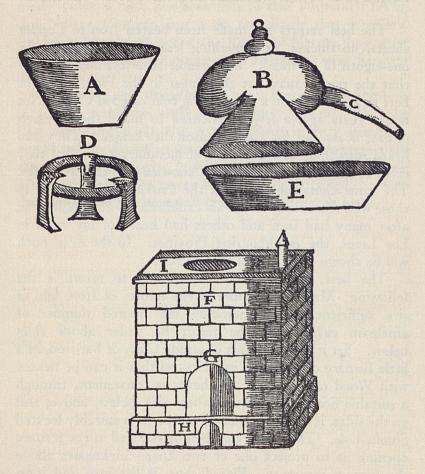
# CHAPTER TWENTY-FOUR

# OTHER AND SURER METHODS FOR RETORTING AMALGAM

The best retorts are made from beaten Iron or Copper sheets, no thicker, or something less, than a Real (about one-eighth of an inch). For greater security, and in order that the retorts may last the longer in the Fire, it will be best to apply outside a close-fitting coat of good Clay. Not many years ago, a few commenced to make these vessels of cast Brass, but for a good reason they ceased. They had heard something about the use of metallic retorts, but they erred in the Execution, lacking a knowledge of the principles. The same thing happened, in the Province of Chichas, to those who tried using cast Brass cauldrons for amalgamating, after many had seen and others had heard of my work in Los Lipes, the neighbouring Province. In the next book will be shown the cause of these errors.

The best, quickest, and safest way to retort is the following: Make the bottom of the retort of Iron, and of size sufficient to accommodate the desired number of amalgam cakes. Let the retort be wider above than Set it on grate-bars of strong Clay, or bar-iron, in a little furnace of sufficient capacity, so that it can be heated with Wood or Charcoal, whichever is convenient, through a suitable firing-door. Everywhere else, below, above, and on the sides, it should be closed, except for a suitably located Smoke-hole. The retort will then be so fitted in the furnace opening as to project one or two finger-thicknesses above the furnace structure. Placed thus, it fits into and joins with another vessel which serves as a condenser. Charge the amalgam on the bottom of the retort, well spread and packed, or made into balls, as may be desired. So that the Silver, even if it melts, may not stick, the retort should first be coated with a wash of fine Ashes or Clay.

Close with a piece like the head of a good-sized alembic, made from beaten Iron or Copper, or of very well vitrified Clay. Let it have a long neck, which, at the small outlet, will admit a finger. Mud the joints well. In a safe place, and where it will not feel the heat of the furnace, locate a



vessel of Stone or other material, full of cold water; let the nose of the alembic enter the water to a depth of two finger-thicknesses. Light the fire in the furnace. Fleeing the fire, the Quicksilver, converted into vapour, will strike against the cool conical part of the head, and be reduced to



its original condition; thence it will pass through the outlet of the alembic to the bottom of the said vessel. The alembic will be cooled frequently with wet cloths, and, if the water in which the Quicksilver is being caught should become unduly heated, it should be tempered with cold water.

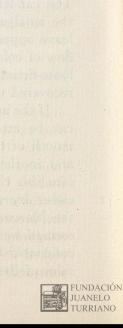
A—The iron vessel. B—Head of the alembic. C—Alembic nose. D—Retort support. E—Pan or vessel filled with water in which the Quicksilver is collected. F—Furnace. G—Fire-door. H—Door for removing ashes. I—Opening in the setting, where the retort comes out and is joined to the condenser. K—The chimney through which smoke

is carried off. It also provides draft for the fire.

The annoyance of luting the joint of the amalgam pot (A) and condenser, and the risk therefrom, may be obviated by making the amalgam pot one palm and a half wider than usual. At a point inside, where the diameter corresponds to that of the ordinary condenser-head, fix a circular channel into which the condenser head will fit loosely. A little farther down than the point to which the condenser reaches, fix the stops or rests of what is called the candelabra, or rack, upon which will be placed the holders for the amalgam. The candelabra will reach up to a finger-thickness above the amalgam pot bottom. Let two small pipes enter and leave opposite points of the channel, to provide a constant flow of cold condensing water. These will not disturb the loose-fitting condenser head. The Quicksilver will thus be recovered without risk.

If the amalgam is retorted in an alembic, the same result can be attained by soldering a channel of Copper to the mouth of the lower vessel, two finger-thicknesses in width and another two in depth; the alembic head will fit loosely into this channel. In this channel the alembic is so fixed, either by a weight or by tying down, that the force of the Mercury vapour may not lift it up. It may also be secured by a large Iron bar passed through the ring of the condenser head and fixed into small recesses built in the sides of the furnace for this purpose.





## THIRD BOOK

OF

# EL ARTE DE LOS METALES

IN WHICH IS DESCRIBED THE TREATMENT OF THE ORES OF GOLD, SILVER AND COPPER BY COOKING (PAN AMALGAMATION.—TRANSLATORS)

### CHAPTER ONE

HOW THIS METHOD OF TREATMENT WAS DISCOVERED

In the year 1590, I was residing in Tarabuco, a town in the Province of Los Charcas, twenty-four miles from the city of La Plata, which is the capital of that Province. Having read of a method of solidifying Quicksilver in an Iron pot, or vessel, I desired, at that time, to experiment therewith, and lacking the aforesaid Iron pot, I made the experiment in an ordinary Copper jar of small size. As I did not obtain the effect expected, I added at hazard some Substances, among them finely ground Silver ore, thinking that these ores might contain certain Virtues, which, aided by the Heat and Moisture of the cooking, would be of importance in my attempt. Briefly, at the end of the cooking I took out a quantity of Silver amalgam. At first, as would naturally be the case with one not experienced in this procedure, this confused me not a little. I soon became enlightened when I noted that what the Mercury had picked up was the Silver content of the ore, and no other substance which might have in part been transmuted.

I remained very well content with this new and short Method for treating ores, which I had discovered through Chance. Since then, through Investigation and Experiments, carried on these many Years, I have bettered it. I have used and publicly advertised it, making no Mystery thereof, neither reserving unto myself this nor other secrets. I have used it more efficiently since the year 1615, when I was curate of Tiaguanaco in the Province of Pacajes, and, on a large scale and with more Profit, since 1617 in the Province of Los Lipes.

After the lapse of so much time, some have attempted to gain for themselves the Gratitude belonging to another, and have sought advantageous premiums in different Parts as the inventors of this new treatment. Nevertheless, they have well demonstrated that they could neither recognize their own Mistakes, nor the Deceptions of others. As for myself, I know for certainty that neither did I learn it of anyone, nor did I have any idea of it until the said occasion. The World is wide, and it may be that in some other Place, or at some other Time, this Process has been used before, although no mention whatsoever is made of it by ancient and modern Writers. The Real Audiencia de la Plata [The Crown's Executive Council.—Translators] conceded me a monopoly, and forebade the use of this Process except by license from me. Without compensation I have permitted all to use it, although I have reserved unto myself certain Details which will be noted in the succeeding Chapter.



### CHAPTER TWO

THE ANTIPATHIES AND SYMPATHIES WHICH EXIST BETWEEN ORES AND MINERAL SUBSTANCES, AS AMONG OTHER THINGS IN NATURE

Many are the Virtues and hidden Properties that God has placed in all the things of Nature; and the less known the Causes, the more marvellous seem the effects. It is in vain that the most subtile of Philosophers tires, and always will tire himself in investigations and discourses on his Reasonings; since, to preserve the Majesty of Nature, and to humiliate overweening human Presumption, the Author of all has hidden these things in obscurity. This human Presumption, though unable to explain that which its own hands touch, nor that which its own eyes see, each day is intent on lifting itself above the Heavens, to solve by puny efforts the Immensity of the Divine Dispositions.

While books are full of details about the Phenomena of Nature, and many are exceedingly well known, not even those accustomed to reason on hidden causes pass beyond vague Conjecture. Antipathy and Sympathy, which are like unto Discord and Concord between one thing and another, they call the foundation of these marvellous effects. Most pleasing is the spectacle which Nature advances in the perpetual Peace and inviolate Concord guarded by some things among themselves, and the capital Hatred and Enmity with which others seem to pursue and detest each other. This was assigned by *Empedocles* as the origin and seed-bed of all the Evil of the World.

This Sympathy and this Antipathy are found among all other things, as well as among the Elements. Even unto the Heavens themselves the Astrologers have gone with their

friendships and enmities, pretending such between the Planets, as sung in elegant verses by Manillo, and as taught by all in the rudiments of the *Justiciaria*. Equal marvels of Nature are seen daily in the behaviour of Plants and Animals. On this subject I could cover not a few pages, though I excuse myself on account of its being inappropriate.

Between Stones and Metals no lesser marvels are to be observed; notable marvels produced by human intervention are the effects of the Magnet on Iron and the effect of that water called *Fuerte* (Nitric Acid), made from half-minerals, in which, as though it were Salt, Silver is dissolved and converted into a liquid, though any accompanying Gold will not be altered whatsoever by this violence. A contrary effect has the same water if in it is dissolved a little Salt; then the liquid converts the fine Gold into a Ruby-coloured liquid, leaving the Silver entire and without damage.

Many are the other results obtained by those who work in these materials. Between the Metals themselves one finds the same Friendship and Enmity as between other things: of Lead, Tin alone is a friend; all others it hates and destroys. Iron, with a particular activity joins itself to Lead, and revives Quicksilver when already nearly lost by fouling. The Magnet [Precipitant.—Translators] of Silver is Copper, which, to the justifiable Admiration of those who see it, attracts unto itself dissolved Silver, and reduces it to a solid. This is an old experience in the World, and one which might have, long before this, opened the eyes of those who treat ores, as to how by this means they might the more surely and easily recover what Silver the ores contain.



### CHAPTER THREE

HOW WATER TAKES UNTO ITSELF THE QUALITIES OF THE SUBSTANCES WITH WHICH IT COMES IN CONTACT

The substances suspended in water, or over which it may pass, communicate unto it their Qualities or Virtues. Thus originate tastes, odours, and colour, greatly differing, as seen in the various Springs and Streams, the diversity of natural Baths, and the many medicinal Virtues encountered therein. Andres Baccio Elpidiano wrote a long, learned and curious Treatise, called Thermis, on this subject; it is of equal interest to Philosophers and Physicians, and in it the reader will find several references to Ores, or Metals.

Ores also impart their qualities to water, and, although it would seem that their Massiveness would be a hindrance, such is not the case. More so is this true with the coloured [Oxidized.—Translators] ores; in a short time the water attracts and takes unto itself something like a subtile emanation of the ore with which it is in contact. water, known and used by Physicians, has been described by two learned Arabs, Avicenna and Raris, who say that the oftener the red-hot Steel is quenched, the more medicinal

is the Virtue imparted to the water.

In the Sixth Book of the said Elpidiano are described the curious and admirable effects worked by the waters of each of the Metals in curing the human Body. These effects are confirmed by that very ancient authority, Scribonio Largo, by Dioscorides and by Galen, through their personal experience. Further, present-day practitioners continue to use these medicinal waters. Elphstadio, in his treatise on Philosophy, testifies to this same effect, and describes this easy experiment to prove it. Melt (so he says) Lead

and throw in water. If now red-hot Iron or other metal is quenched in this water, it will become most docile and soft. On the contrary, if melted lead is thrown a few times into water in which Iron, Gold, Copper, or other hard metal has been quenched, it will become harder. This is a certain sign of the qualities which one and the other impart to the waters, and receive from the metals, through heat. On this principle Marcillo Ficiño founded his reason for charging all the Learned Ones to keep secret and mysterious the Potable Gold, of the virtues of which many speak, in which some believe, and which exceeding few have experienced.

On this mysterious Solubility also is founded the quick and easy treatment of the ores of Gold and Silver by cooking in Copper vessels; in vessels of clay, or other metal, the treatment is prolonged and nothing recovered. The virtue imparted to water by the Copper in which it is boiled livens the Quicksilver and cleans the Silver, so that it is easily picked up or amalgamated. Water which has been boiled in iron, films over Quicksilver and makes it torpid and useless. And, although water boiled in Copper is not itself suitable for recovering Silver, neither recovering, embracing nor attracting it, through the Contrariness of the qualities of Copper imparted to it, the Quicksilver is aided in amalgamating the silver, as will be described in more Detail in the Chapters which follow.



### CHAPTER FOUR

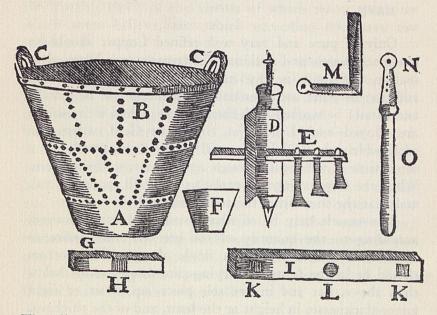
THE MATERIAL FROM WHICH SHOULD BE MADE THE CAULDRONS USED IN THE TREATMENT OF ORES OF GOLD OR SILVER; AND ALSO THE SHAPE THEY SHOULD HAVE

Only of pure and very well refined Copper should be made the vessels and cauldrons for treating ores by amalgamation. If there is any mixture of Iron or Matte, in addition to other inconveniences, the metal will be brittle, and cannot be worked with the hammer. And if the sheets are alloyed with Lead, Tin, Silver, or Gold, substances with which the Quicksilver will easily amalgamate, in a short time it will pass through and penetrate the bottom. When the Copper Ingot is cool, cut away all spongy metal,

and beat the sheet from the solid part only.

The vessels may be of whatsoever capacity is desired, according to the quantity of the ore one may desire to treat most comfortably as a single charge. The bottom should be in the form of a frying-pan, more narrow below than above, flat and in one sole piece, up to six or eight finger-thicknesses in height at the least, and of the thickness of half a finger. On this bottom, and around it, there will be riveted sheets of Copper, wider at the top than at the bottom. The sheets will be half the thickness of the bottom, or, even something less will suffice. In these proportions the cauldrons may be augmented for the size and quantity that may be desired. Rivet these sheets to the bottom, and to each other, with well-tightened Copper rivets. When the necessary height is attained, finish off with a rim of Copper or Iron, as is customary among Coppersmiths. Attach two strong upright Lugs in which, as will at once be explained, there has to be fixed the bridge of the Stirrer. For greater security, apply to the outside joints a paste of Quicklime or Ash, kneaded with Bull's Blood, so that neither water, ore slimes, nor Quicksilver can get through.

Make a Stirrer of the ordinary pattern, although not of such heavy timber. Less strength is needed, on account of the aid from the boiling, the fineness of the Sand, and the great amount of water that must be mixed with the ore.



The die on which the Stirrer moves must be made from Bronze. Attach the die to a Copper strip, two finger thicknesses wide and one-half in thickness, and as long as the diameter of the cauldron. The strip should be well adjusted to the bottom, fairly tightly, so that it will not shift. The ploughs of the Stirrer do not need to be equal in length; those nearer the centre may be longer, and those nearer the circumference shorter, as may be judged best by sight, according to the proportional width of the cauldron. Fix the bridge in the two lugs with Wedges.



The crank may be turned by a fairly long wooden Sweep fitted with an iron ring to drop over the end of the Stirrer shaft above the crank; thus the cauldron can be stirred from the outside. Even if the cauldron is wide, and the heat from boiling water very great, it can cause no inconvenience. The rest of the Stirrer is of the same construction as used in ordinary clean-up tubs.

A—The one-piece bottom. B—Cauldron built up from sheets. C—Lugs. D—Stirrer. E—One of the four arms with ploughs of unequal length. F—Sheet from which the cauldron is built up. G—Copper strip with die, on which the Stirrer rests. H—The die. I—Stirrer bridge. K—Holes for the lugs. L—Hole for Stirrer shaft. M—Crank. N—Iron ring, and O—Wood sweep for turning the crank.



### CHAPTER FIVE

WHAT ORES ARE BEST SUITED FOR TREATMENT BY COOKING (PAN AMALGAMATION)

By heeding the Warnings given here, any class of ore may be treated in the copper cauldron. Those which more quickly and easily give up their values are oxidized ores, mixtures of oxides and sulphides, silver halides, and native Silver. Such ores need no reagents, nor preparation whatsoever, although by roasting they are cleaned and purified, thus yielding their Silver more easily. This is especially the case with mixed sulphides and native Silver. The other kinds of black silver ores, as has been said, are best smelted, on account of their nature. If not smelted, then it is best to roast them until they change colour and lose their lustre, treating them at once by cooking. Nevertheless, they can be treated raw, though at the expense of much more time than with other ores. To treat by cooking, however, it is necessary to add Copper Sulphate, Alum, Salt, or something containing Salt, like urine, or strong brines, which have the effect of roasting, in that they remove the brilliance and glassiness that prevent amalgamation of the ores. Nevertheless, these reagents act more quickly, and eat the Copper of the cauldrons, unless they are held back, as explained further on.

The holding-back of the reagents also has its inconveniences. He who would treat the raw black silver ores, after grinding should incorporate an abundance of reagents, as well as much salt and sufficient water. The charge should be thoroughly worked up until it is seen that it changes colour, as will happen when helped by time, heat and the mixing. This effect will be attained more quickly

and with less risk from excessive working over, if the ground ore and reagents are thrown into a tub and beaten strongly with the stirrer until it is seen that the colour has changed. The Copperas and Salt will then be removed in the manner already explained, and the charge can then be safely treated by cooking.



#### CHAPTER SIX

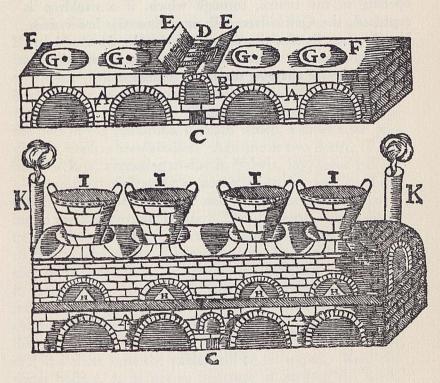
HOW TO ERECT THE CAULDRONS IN WHICH ORE IS TO BE TREATED

In whatsoever way Fire is applied to the cauldrons so that the contained water will boil, there will be attained the desired Effect, which is to remove the Silver quickly from the ores without undue loss of Quicksilver. However, to obviate a part of the cost, and prevent difficulties which might arise, it is best to erect the cauldrons in the following manner:

Make a furnace in the shape of a Box, using Adobes of strong mud, kneaded with clay, sand, dung and salt water. The width of the top opening will be such as is necessary for the cauldrons, and the length to correspond to the number of cauldrons. Let there be one flue for each pair. Four cauldrons will be sufficient; thus the furnace will be four and a half times greater in length than in width. In the middle of this space erect two small walls, distant the other by half a Vara. Place grate bars one from the of Iron, Adobes or Bricks, such as are used in reverberatory furnaces. This is like a floor on which to light the fire and sustain the wood and coals in such a way that the ashes separate and fall into the ash-pit. On each side of the firebox leave an opening to communicate with the chambers under the cauldrons; the floors of these chambers must be one palm higher than the grate bars. This floor under the cauldrons is built on arches which correspond in size and number to the cauldrons to be used, so that one arch corresponds to each cauldron. In the upper arch or roof of the furnace leave sufficient space for the entrance of the cauldrons. At the ends of the furnaces leave two openings or

chimneys for the escape of smoke and to provide draft. The part of the floor immediately under each cauldron will be made somewhat concave; in the lowest point of each concavity, leave an opening three or four finger-thicknesses in diameter, communicating with the bottom floor, also made bowl-shaped in its entirety.

With the furnaces built in this way, the cost of wood fuel



for cooking is reduced by one-half. Also, much of the fuel necessary in roasting can be saved by charging pieces of ore in the available space under the cauldrons, through two opposite doors; these can be closed by *Adobes* when convenient. If by chance, when a charge is being boiled in an old cauldron, the bottom should be ruptured, the Quick-silver, most exposed to risk on account of the fire, would escape through the hole in the upper floor to the lower floor



where it would not be exposed to heat, and a considerable part would be recovered with little or no loss.

A—Arches on which is built the floor of the furnace. B—Fire-door. C—Ash-door. D—Grate-bars. E—The two walls and openings through which the fire is led to the two groups of cauldrons [Fire-bridges.—*Translators*]. F—Floor of furnace. G—Concaves beneath each cauldron, with an opening in the centre, through which, if a cauldron is ruptured, the Quicksilver will escape to the lower floor. H—Openings for charging ore to be roasted. I—Cauldrons. K—Chimneys. L—Another door at the front of the furnace, also for charging ore to be roasted.

#### CHAPTER SEVEN

#### INSTRUCTIONS FOR TREATING ORES BY COOKING

Grind and screen them to the greatest Fineness possible. If, when the ground ore is taken between the fingers, there can be felt the sharpness of coarse Sand, throw it into tubs, or Bateas, with sufficient water, stir very well, and, after a brief rest the fine will separate from the poorly ground, which will settle to the bottom. Charge the slime and water into the pots or big cauldrons, beneath which, a short time previously, fire has been kindled. Add one or two Botijas (Rawhide buckets, averaging to-day in Bolivia, say, seven gallons -Translators) of clear water, according to the capacity of the cauldrons together with the necessary Quicksilver, according to the Richness of the ore. This, however, should never be less than enough to cover the bottom of the cauldron, so that in whatsoever part ore may settle, it will be in contact with Quicksilver. Continue stirring slowly, although, in boiling, the water will cause a certain amount of movement in the ground ore, if the Sand is not very coarse. Through this stirring with the Quicksilver, the Silver will unite with and become incorporated therein, and in a short time the values will be recovered. Keep the water boiling, so as not to interrupt or prolong the work. To make up for the loss in boiling, add an equal amount of hot water, or, by a Launder of easy slope, continuously run in water in such proportion that it will not stop boiling, but vet will equal the consumption; this can be controlled easily by watching the rise and fall of the pulp line in the cauldrons.

Judge the quantity of ground ore to be treated at one charge, according to the size of the cauldron. If there is

too little ore and too much water the work will be multiplied. If there is too much ore the charge will be too thick, making difficult the agitation caused by boiling. Using a ladle from time to time, take a Sample from the bottom to determine the progress of treatment and whether Quick-silver should be added, or, if desired, a part of the amalgam already formed may be removed. The slime or fine sand taken out in the sample should be returned to the cauldron until the charge is finished, and the ore has given up all its Silver. This state will be recognized through applying the Instructions given further on.



# CHAPTER EIGHT

WHICH SHOWS THAT THIS IS THE TRUE WAY TO RECOVER VALUES FROM ORES BY AMALGAMATION, WITH NEITHER LOSS NOR CONSUMPTION OF QUICKSILVER, AND IN THE SHORTEST TIME

The natural affinity and liking of Quicksilver for the Metals is sufficiently proven, when other Arguments might lack, by the way it unites with, penetrates and drinks them, converting them into what we call amalgam. There is no other thing in the World that has this quality; it stands apart from all the other Metals in the World. Neither is there an Equality in the friendship it manifests towards the metals. There are degrees, according to their perfection, and it is thus that it unites most speedily with Gold; next Silver; after these, other metals; and lastly with Iron.

This seems to confirm what has been said about the Genesis of Iron. On this property of Quicksilver is founded the present-day treatment of the ores of Gold and Silver by amalgamation, an Art not practised in ancient times. Not even Georg Agricola, in his copious work on the treatment of ores, makes mention of it, although this work was written only eighty-seven years ago. He does touch lightly upon the assaying of Gold, and on how to recover that which is finely divided. Quicksilver in its natural state is always disposed to seize upon and unite with Silver; but the ores of silver are rebellious to Quicksilver on account of the veil or film with which Nature provides them.

It is shown by Experience that the grinding and heat of the operation, together with the mixture of reagents which clean, consume and wear off this film, bring the ore, little by little, to such a condition that immediately the Quicksilver and Ore unite. Even the inexperienced must admit that in the treatment of ores by cooking, all these factors concur with great improvements. The more the charge is worked over, the better, and it is thus that fifteen minutes' boiling gives the same results as are attained after Days and even Months in ordinary work. The virtue which Copper imparts to the water cooked in it attracts and conditions the Silver better than a multiplication of reagents; but heat is, without comparison, the greater factor, penetrating and taking effect on all part of the charge. Thus, by this method, no more Hours are occupied in recovering the value of the ore, than Days by the ordinary process.

The Quicksilver cannot escape, nor is there risk of loss, by this process. To claim that it might be expelled by the considerable Heat would show more than Ignorance, because it is protected by the covering water. Even children know how to boil Oil in a paper, without burning the paper itself, and how to place in lighted coals an Egg, around which has been tied a Thread, without burning the Thread. Even when water has been boiled strongly in a cauldron, the bottom will not impart a heat unbearable to the hand that touches it. In great vessels of pure lead, salt water is cooked in Germany (and may so be done wherever desired) until the Salt crystallizes; yet the violence of the fire does not alter this soft and easily-melted metal.

The troubles called consumption and loss of Quicksilver, as has been shown, are due to the excessive subdivision caused by grinding, whereupon it escapes with the Water and Slimes. This inconvenience does not exist when ores are amalgamated by the cooking process, because all the Quicksilver is in the bottom of the cauldron in one body. Without an excessive movement, if the treatment is carried on as it should be, floured Quicksilver will never be seen.

These clear Assertions always conform with actual Experience.



### CHAPTER NINE

HOW TO RECOGNIZE WHEN THE ORE HAS GIVEN UP ITS VALUE; AND HOW THE CHARGE SHOULD BE CLEANED UP

The determination to a certainty, by fire assay, of the Silver contained in the ores to be treated by amalgamation, is a necessary preliminary, whatsoever the method used. The determination of whether the ores have vielded their values in the cooking is even more easy, because he who may so desire can remove nearly all the amalgam which the charge should render, before starting the clean-up. The upper part of the Quicksilver is that which is continually taking up Silver, because it is immediately in touch with the ore containing it. The heat communicated through the bottom of the cauldron maintains the amalgam in suspense, and does not allow it to unite equally with the whole body of the Quicksilver. And it is thus that nearly the whole of the amalgam is above, as a cream of two, three or four fingers' thickness, according to the richness of the ore, and the time given for the amalgamation. It is easily removed with spoons. The slimes may be washed off in clear water as the amalgam is ladled out; it will remain white and pure without necessity of other treatment. If the ore is very rich this skimming is important, and additional Quicksilver should be charged, so that the treatment is shortened, the balance of the Silver is quickly recovered, and the charge is finished.

Also, without removing the amalgam, in the manner aforesaid one may determine, by studying the purity and colour of the amalgam in a ladle sample, whether the ore has yielded up its value. This is the practice in ordinary amalgamation, though not always the best, for the Reason

explained further on. The most suitable and appropriate Rule in amalgamation by cooking is to stir up a small amount of the fine charge two or three times in the horn spoon, with a little Quicksilver. If it becomes bespangled, through picking up some Silver, the values in the charge are not yet all recovered. If it picks up nothing, the charge has nothing more to yield. The reason for this is that the ore is so well conditioned that, without any loss of time whatsoever, any Silver that has remained in the charge has become linked to the clean Quicksilver. When it has been proven by the rules given that the charge has yielded up its value, cease firing. Remove the bridge and take out the Stirrer. When the charge ceases to boil, bail out the slime water in Bateas, or drain through spigots placed in the cauldrons just above the setting. It may then be run off in ditches where it will cause no disturbance, and with the assurance that it will carry no Quicksilver nor Silver. Remove the sand which may have settled on the amalgam. If the transmitted heat should continue persistently to impede, correct with cold water thrown into the cauldrons. For the rest, proceed as when using the ordinary clean-up tubs. And, for greater satisfaction, do not throw away the tailings until they have been assayed by fire. If there is necessity they should be reground.



# CHAPTER TEN

THE DISADVANTAGES OF THIS PROCESS, AND PRIMARILY THE DANGER OF RUPTURING THE CAULDRONS

That which at first sight and in the common Opinion makes this Method of treatment seem to be of little importance or advantage is the ease (according to the general Understanding), with which Quicksilver penetrates the bottoms. There is the manifest risk of losing all the Silver in the ore, as well as other things. The objection is not without foundation; because such a thing happened some years ago in the Province of Los Chichas, I being at the time in the neighbouring Province of Los Lipes. A certain man who owned a Mill at that place, knowing that I was regularly recovering amalgam by this Method, tried, without any further Knowledge, to carry out the Method on a working scale. The cauldrons will last a long time if they are constructed rightly and in the manner described in the Fourth Chapter of this Treatise, where, as an experienced operator, I testify that a very thin Copper jar served me for five years continuously in this work, without breaking.

The aforesaid mill-owner was, at the same time, a Founder of Bells; he cast the cauldrons in Moulds, and with the customary Alloy of Tin, both very gross errors. He had only a hearsay knowledge of this Method of amalgamation, and could only follow it up to failure, because the Water and Quicksilver could not protect the thick bottom

against the violence of the Fire.

Therefore it had, of Necessity, to melt. That part touched by the Quicksilver also was easily penetrated, because of the alloy.

The slight resistance of some cauldrons or jars to Quicksilver is due to soldered Joints or to the Copper sheets being beaten out from spongy ingots, causing flaky sheets,

easily penetrated.

The greatest damage received by the cauldrons is in the circumference at the junction of the Quicksilver and Pulp, due to the continuous pounding of the boilings. It is remedied by a band of Copper of the thickness of a Real de a ocho (Spanish coin of the epoch, about one-eighth inch thick—Translators), or a little more, and three or four finger-thicknesses in height, which is adjusted above the bottom to the inside wall of the cauldron. This ring receives the shock of the boiling, and, when in time it is worn out, it is replaced at little cost. All the Copper which may have been consumed will be replaced by Silver.

One may also apply a Paste to that part of the bottom covered by the Quicksilver, thus totally obviating amalgamation or penetration. Make the Paste from lime slaked in wine, slag of iron, and water-worn pebbles, finely ground, and incorporated with the well-beaten whites of eggs, or with oil. Firstly, clean the Copper well; then rub with oil, and apply the paste or varnish at once. If all the cauldrons are repaired with this paste they will last a very long time. However, the paste detracts from the Virtue which the Copper communicates to the water and ore with which it is in contact; therefore this remedy should only be used in that part of the cauldron to be occupied by Quicksilver.

It would not be difficult to experiment with other means of protection, such as enamels, glazes, sulphur, smoke, eggs burnt in the bottom of the cauldrons, and other things which blacken the copper and serve as a film to resist the attack of Quicksilver. And if finally, through age (which consumes all things), a cauldron is ruptured, through the Neglect of him who should have detected and prevented the damage, this accident will not be serious, on account of the construction of the Furnace, as described in the Fifth Chapter. [That is, the holes in the upper floor of the furnace will allow the quicksilver to pass through and collect on the bottom of the furnace.—Translators.]



# CHAPTER ELEVEN

WHICH DISCUSSES WHETHER OR NOT THE AFORESAID METHOD IS SUITABLE FOR LARGE SCALE WORK

One of the most common Errors I have seen, even among Persons who presume to know much of the subject, is their self-persuasion that experimental results cannot be duplicated on a working scale. When Persons are not able to duplicate the small-scale test, it is a sure sign that they proceed by Chance and without Reason in what they are doing. Having a certain Knowledge of what they did, they would know how to maintain the necessary Proportion and proceed on a large scale in accordance with the experience gained in small-scale work. A handicap to this Process is the belief of some that it is not possible to duplicate experimental results. This is a manifest Deception, and opposed to the very Nature of Things, although in some Parts and on some occasions, such duplication may not be practicable.

The material from which the cauldrons are made, which is Copper, is by no means lacking in these Kingdoms; rather is there an Abundance of its ores. The fabrication of the cauldrons is easy, as only the bottom (which carries the Quicksilver) has to be of one piece, and that not large. The rest is added as sheets, until the size desired is attained, without any difficulty whatsoever. It is then surrounded and fortified with lime and brick, for greater firmness. A vessel of this sort, as ordinarily used in the heating and boiling of Soap or Sugar, will hold from fifty to one hundred gallons of water. The boiling with Quicksilver must necessarily be aided by stirring the considerable quantity of ore in the cauldron, with the Stirrer. Thus, through the natural

Virtue of the Copper (which accomplishes the conditioning of the ore), and the aid of Heat, the Quicksilver escapes flouring, and of necessity it quickly picks up the Silver without Loss or Consumption (as these Occurrences are called).

Only he who judges it impossible to boil large quantities of water in adequate vessels, either fashioned of Copper or lined therewith, has grounds for denying that this Process can be used on a large scale; and one can well see on what a false principle this belief would be founded. Even if, by Imagination, one could conceive of a District which had Copper but had none to elaborate it, and which had neither wood nor other material sufficient to sustain fire, this would only be the result of Chance, and would not remove the certainty nor the possibility of the Art, which, like others, cannot be practised without fire.



# CHAPTER TWELVE

# THE CONSUMPTION OF FIRE-WOOD

The inexcusable consumption of Fire-wood is the thing which, with more apparent Reason, might cause some Discredit to this method of treatment. Necessarily there must be a great store of fire-wood, upon which are spent many Ducats. Nevertheless, the distrust caused when only the consumption of Fuel is considered is modified when one compares the Expenses and Savings of this and other methods. Moreover, I know, by experience in the many mining Districts in which I have been, that the Provinces of Chichas, Lipes, Charcas Paria, Carangas, Pacajes and Omasuyo abound in Fire-wood; and, in the most barren and almost uninhabited Highlands, Nature has provided in great abundance what we call Yareta, more suitable for burning than ordinary Fire-wood because it is so greasy, and full of resin. In order that this matter may be more clearly understood, I will calculate the cost to-day in this Imperial Village of Potosí for the treatment of one Cajon (5600 pounds) by the ordinary method, as against what the treatment by cooking would be. I choose Potosí because it is the mining District where wood is known to be the scarcest and dearest in this Kingdom.

There is spent in grinding the charge (though the figure is not exact, because some charges take more Time than others) approximately ten *Pesos* in twenty days; two *Pesos* in reagents (two *Pesos*' worth more of salt than in the cooking treatment, which needs very little); and three *Pesos* in the washing (clean-up); and if ore yields around fifty pounds of amalgam, or one hundred and sixty ounces of Silver, there will be added ten pounds of Quicksilver for

what is called Consumption and another three pounds for Loss. This Quicksilver, at one *Peso* per pound, makes thirteen *Pesos*, and with the seventeen *Pesos* of other expenses amounts to thirty.

In a furnace such as is used to-day for roasting ores, there is consumed each Shift (as the time between daylight and darkness is called) two Ouintales and a half (250 pounds) of Yareta, and the same in the night, sustaining a continuous fire. This, at six Reales (seventy-five Centavos) the Quintal (and at times it is worth less), amounts to three Pesos, six Reales for the five Quintales. Divide the Cajon (5600 pounds) among eight cauldrons of moderate size; fire through the two furnace doors, arranged in the furnace as described in Chapter Five. At the rate used to-day, ten Ouintales of Yareta will suffice to fire these cauldrons for twenty-five hours. And although so much time is not necessary for the ore to yield up its value, to better prove the case, allow double the consumption of Yareta or twenty Quintales. This will amount to fifteen Pesos and, with eight Pesos for Indian Labour, a total of twenty-three. By this calculation a saving of seven Pesos is attained. One recovers the Silver which would be carried off (in the ordinary method) in the thirteen pounds of Quicksilver, and this is equal to another twenty-four ounces, worth nineteen Pesos, or a saving on each Cajon of more than twenty-five Pesos.

There is also a gain in Time, as the treatment of one month is reduced to one day. The ores yield a sixth more of their content, and nothing is left in the coarse sand, because one can and should treat Slimes only by this method.

And if, with ores yielding around fifty pounds of amalgam to the Cajon, there can be saved more than twenty-five Pesos, through treating them by cooking, who cannot see the great sum to which this would amount in treating ores of a higher grade, which would necessarily consume more Quicksilver in the ordinary process? In each four retorts of three hundred and twenty ounces of amalgam there will be a saving of two hundred and thirty-six Pesos, which is



enough of a Gain and Saving to help cover the cost of the cauldrons. Moreover, that part of the cauldron which gradually becomes amalgamated and scraped off will in time have yielded more than the price of the cauldron itself. The amount of Copper in the amalgam is too little to detect by assay. This intercharge of Copper and Silver not only compensates for the cost of the cauldrons, but is a source of no little gain as well.

When the ores of a mine may seem to be of too low a grade to treat by this method (and there is no mine but has some low-grade ore) let the high-grade be sorted out and amalgamated by cooking. This can be profitably done, and it will be of great advantage to the Miners to be able to get

to-day the Silver in the ores they mined yesterday.



#### CHAPTER THIRTEEN

#### THE DRAWBACKS TO THIS METHOD AND THE REMEDIES

The speed and great violence with which the Quicksilver and Silver unite in this method of treatment is the reason why at times the amalgam is baser than that obtained in the ordinary method. This is most likely to happen in the treatment of ores containing much heavy Plomo, called Anco, which (as has been said before) is impure native Silver. The Quicksilver picks it up quickly through the aid of the boiling, and no time is given for the elimination of the impurities. It might well happen that it would purify itself by continuing the boiling, but to avoid excessive Delay it is not always best to do this. Therefore, when it is proven that the ore has yielded its Silver, one may stop the treatment and take out the amalgam as though it were pure. Wash it with clean Quicksilver, without adding water; on stirring a few times with the hand, all the impurities will rise to the top. The scum which may be on the surface is to be removed as many times as necessary, until the Quicksilver and amalgam are clear as a mirror.

The leaden scum taken off the top is put back in the next charge, if it belongs to the same Owner; or, it may again be washed with Quicksilver, as before, and thus reduced to but little volume; or, it may be worked over in a *Batea* with salt and ashes, or lime, being rubbed well with a piece of tile, as in the ordinary clean-up. Lastly, it may be retorted, melted and refined on a cupel bottom.

When the ores treated abound in Sulphur, as do all kinds of black Silver ores, the Quicksilver will become very black during amalgamation and will not pick up the Silver. It will be a wise precaution to have the ores roasted to eliminate the Sulphur, as has been said before. He who, through Curiosity, desires to treat the ores without roasting, may do so by adding, while cooking, Copper Sulphate, Alum or Salt, or substances which contain Salt, such as brines or urine. With the change of colour in the ore, the Quicksilver will become clear and amalgamate with the Silver.

Much would be saved by treating the black Silver ores in this way, if the ensuing damage to the cauldrons was not so certain. Both the weakening of the cauldrons and the cost of reagents are to be considered, and therefore the black Silver ores should not ordinarily be treated by this method; nor can the ore be advantageously prepared by cooking in some other kind of vessel with the reagents, but without Quicksilver. Vessels made from clay, even the most thickly glazed, will leak or filter, while those of iron will corrode and turn to copper. I cite these facts so that no one may suffer from such mistakes. Something may be done by using cauldrons of copper or iron, entirely coated inside, as has been explained, or by many times working over the black Silver ores with the aforesaid reagents, according to directions given. Nevertheless, it is easiest to roast the ores; only that the possibility of treating the ores raw may be seen, have I written the above.



### CHAPTER FOURTEEN

HOW AMALGAM MAY BE OBTAINED FROM COPPER ORES BY COOKING

Exceedingly rare are the ores of Copper which yield amalgam when ground or incorporated with Quicksilver. Among the many Copper ores which I have seen in all these Provinces, one only have I found which would do it. This I found on a Plain in the Province of Los Lipes, a little more than one league from Sabalcha, and on the road to Colcha. It is an ancient Indian working, and although the ores are rich in Copper, they carry no Silver whatsoever.

The little care manifested in sorting the ores proves to a certainty that the Indians sought only the finest of the Green and Blue pieces, which they called *Cibairo*. Associated with this ore there is a mixture of some kind of impure native Copper which will unite with Quicksilver. It is the only Copper ore I have seen which will yield amalgam in the ordinary treatment of Silver. By cooking, however, all Silver-bearing Copper ores will yield their value, if treated by the method and with the precautions which follow:

The cauldrons in which the Copper ore is to be treated must be of Iron and of no other material, if the desired results are to be attained.

All kinds of Copper ores, except the Sulphides, we call *Pacos* (Oxides). They may be green, light, dark, or of some other colour. There is needed no preparation, except fine grinding and the cooking as with the ores of Silver.

The sulphides of Copper, whether they are steely or brilliant, or whatsoever colour they may be, one must roast until they have lost their lustre. And because in the roasting there is produced much Copperas (Sulphate) the charge must be washed as described before, until it is all removed. Boil the charge at once, and all the Silver which the Copper ore may contain will be reduced to amalgam. If the roasted ore is charged into the iron cauldron (without removing the Copperas), it will wear it out, and in a short time convert

it to fine Copper.

In addition to the aforesaid, the cauldrons of Iron possess the inherent and particular virtue of livening and reviving the Quicksilver when almost destroyed and converted into another substance. This is but another of Nature's marvels, to be studied and admired. Quicksilver is the same, in this respect, as Solimán (Corrosive Sublimate) although the latter is very different in that it is soluble in water like common salt. Boil this ground sublimate with water in an iron vessel, and it will be reduced at once to its original form of common and lively Quicksilver. The effects of this occult property of Iron have been demonstrated since the custom of using it (finely divided) in the charges was introduced, thus stopping to a great extent the loss of Silver.

In the cooking of a charge, this Virtue is quickly and easily made available through the greater heat imparted. He who would care to fully enlighten himself may cook ground Sublimate in a vessel of other material, as long as he likes; but, boil the water as much as he will, no Quicksilver will be seen. Let him throw a piece of Iron into the vessel, and within a short time he will find the sublimate reduced to liquid Quicksilver. It is better, though, if the vessel be

entirely of Iron, as has been said.



# CHAPTER FIFTEEN

HOW TO MAKE A BOILING AMALGAMATION CLEAN-UP ON CHARGES WHICH HAVE BEEN COLD AMALGAMATED

Although the Reader has been warned of the causes of the loss and consumption of Quicksilver in ordinary amalgation, and partial Remedies have been pointed out in the treatise given on this subject, it would be most difficult (even by obeying all Instructions) to obviate entirely these disturbing evils. It may happen that a charge will get into such condition that the Quicksilver becomes soluble, as has been said concerning Sublimate. In this case none of the previous Warnings is of avail, and it is not only advisable but necessary to clean up the said charge by cooking in large iron cauldrons, arranged in the way explained for the Copper cauldrons. Thus, with a few boilings, aided by the movement of the stirrer, the floured Quicksilver will amalgamate with the Silver, and that Quicksilver which may have become soluble will be restored to its original form. That this transmutation of the Quicksilver in the charges is not impossible, seems before now to have been proven by the experience of the many amalgamators who have recovered neither Silver nor Quicksilver, when both were abundant in the charge. There is not sufficient ground for attributing this total loss to the floured Quicksilver.

In addition, there are often present, in the charges, substances which combine with the Quicksilver and convert it to Sublimate, but in the absence of the somewhat dry and intense Heat which is necessary to the action of these Substances, the change cannot be attributed to them. Also, Nitric Acid will dissolve the Quicksilver, and frequently the ore will be accompanied by substances very

similar to those from which it is distilled. In such cases. the vapours and moisture will reduce the Quicksilver to a liquid. Although these vapours are not so strong as the distilled acid, it is within reason to attribute these effects to them, even though the changes do not occur with the quickness and violence attending the use of common Nitric Acid. Suppose, then, that the Quicksilver becomes soluble; it is clear that it will be lost, whatsoever care is used, when the charge is washed; and all will be lost without remedy, if the charge is not cleaned up by boiling, aided by Iron. And although it might savour of an arrogant Temerity to deny that Nature provides some other thing to give this same effect, to this day at least it is not known if there be such. The truth of this will be recognized by those who are well versed in the Philosophy of the Transmutation of Metals; those who are not so learned will have to believe it.

If cauldrons of Iron are lacking, Copper, well arranged in the usual manner, may be used to wash the ordinary amalgamation charges. Cook and stir until a test of the surface slimes gives no sign of floured Quicksilver. Thus will be recovered almost all the Quicksilver which, as loss and consumption, would otherwise have been short, and the ore will better yield the value it has contained. There may also be placed in the cauldrons, while the charge is being boiled, some bars or pieces of iron, as before mentioned; these will aid in the reduction of the Quicksilver that may have become

floured, or dissolved.



# CHAPTER SIXTEEN

# THE AMALGAMATION OF RICH ORES OF GOLD AND SILVER

The ore in which pure Gold or Silver is visible, mixed with rock, is called Machacado. [This word is still generally used in Southern Peru, Bolivia, and Chile, to designate ores carrying visible gold, silver, or copper.—Translators.] Even though it may not be so rich as the sight judges, there is need of guidance as to the method of treating it. If it has to be amalgamated, it can neither be ground well, nor will the Quicksilver seize such coarse Gold and Silver. If treated by smelting the dry rock, without flux to accompany, it is a very great disturber for the furnace, whatever the method, and the metal and rock cannot be separated without risk or much loss. This was the experience of those who discovered the beautiful and rich Machacado ore of Turco, in the Province of Carangas. There was a heavy loss until a friend of mine (a miner then, but now a monk of the Franciscan order) taught them the method of treatment called Tintin (mortar and pestle).

In a hard Rock make a round concavity of one-quarter Vara or more in diameter at the top, the same or more in depth, like unto a Mortar, with the circumference diminishing, as that of a pyramid, until it terminates below in a space of no more than four finger-thicknesses. Charge into this space sufficient Quicksilver and the Machacado ore broken to pieces. Crush with a heavy iron bar, rounded at one end, as is the Pestle of a Mortar. Through the strong agitation the Quicksilver will amalgamate with the Gold and Silver. The fine slime goes off in the water, which continuously enters the hole on one side through a narrow Launder and flows out on the other.

Collect these slimes in a pit and treat them later with Quicksilver, as before mentioned, when they will yield considerable profit. This is very necessary, because the Ruby Silver and Black Silver ores or any other kinds of ores, even if they are very rich (and these at times accompany the *Machacado* ore), so long as they are stone-like, and so are ground and converted into Powder, will escape from the *Tintin* without yielding up their silver.

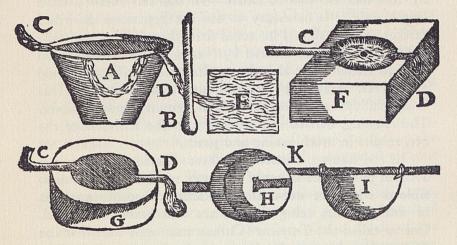
The quantity of ore which can commodiously be treated by this method will be small. To use this method on a larger scale it is necessary to use the apparatus described farther on. It should be noted first, though, that not only the free-milling ores created by Nature in the mines should be thus treated, but also the products containing free Gold and Silver, obtained by roasting lump Sulphide ores. This is especially true in those ores which contain tarnished Silver. The roasting, carried out according to the Richness of the ore, results in much saving and profit.

In the mining Districts of these Provinces, where, on account of the lack either of Water or of Money, it is impossible to construct wet-crushing plants, two other methods of fine-grinding, using Stones, are well known and used. One is called the Trapiche (Chilean mill) and the other the Maray (Rocking stone). [Now usually known in Bolivia as Ouimbalete.-Translators.] Both use two large and hard pieces of stone, the lower one, called Solera (Sole-piece) being imbedded on a level with the ground. The upper (crushing) stone of the horse-driven Trapiche, is in the shape of a Wheel, or whole Cheese, like unto the Atahonas, or olive mills. upper stone of the Maray is like unto a Half-moon or Crescent. To the upper part a pole is tightly lashed, so that two Workmen, grasping the extremities, can rock the stone without much fatigue. Through the weight and the force of the rocking blow, the ore is easily broken down.

The construction of both of these devices is simple and familiar, and therefore I do not stop to describe them. I would only say here that in grinding free-milling ores the



Sole-pieces should not be level, but with a concave path sufficiently large to allow the runner to move freely. Water enters at the highest point of the Sole-piece, through a narrow Launder. At the bottom of the concavity is the necessary Quicksilver. Throw in the ore to be ground, and when it is fine enough the free Gold and Silver will be taken up by the Quicksilver; the balance, converted to a fine slime, will flow off in the water through another Launder; it will then be recovered and treated as previously described.



A—Tintin (Mortar). B—Barreta (Pestle). C—Entering water. D—Slimy water. E—Cocha or pit for saving slime. F—Square sole-piece of Trapiche (Chilean mill) or Maray (Rocking-stone). G—Round sole-piece. H—Runner of the Trapiche. I—Maray (Rocker). K—Long pole to rock the Maray.



# FOURTH BOOK

OF

# EL ARTE DE LOS METALES

TREATING OF THE REDUCTION OF ALL CLASSES OF ORES
BY SMELTING

#### CHAPTER ONE

CONCERNING THE USE AND NECESSITY OF SMELTING

The method most generally used for separating Metals from the Earth and Stones with which they are begotten, in order to reduce them to their due Purity and Perfection, and the method (at the same time) most appropriate and in conformity with their Nature, is by means of Fire, in ovens, which when used for this purpose are called smelting furnaces. This was practised in the World from the beginning of the knowledge and use of Metals, until the treatment of ores by amalgamation was discovered and put into practice in this Imperial Village of Potosí, the most famous and richest of the finds of this New Century and New World. And, although, as has been said in previous treatises, all the ores of Gold and Silver may be amalgamated, for many of them smelting is necessary, and for the very rich it is more suitable; and it is thus that its use in this Village, and in other mining Districts of the Kingdom, has never been interrupted. The base metals must necessarily be treated by fire, and by it all may be perfected. Vain will be the pretensions of him who is trained in the art of treating ores, even when amalgamating Silver alone, if he does not know how to smelt and refine, at least on a small scale, as has already been explained, in order that he may know of a certainty the Grade of his ore and what he should recover.



### CHAPTER TWO

THE MATERIAL FROM WHICH SMELTING FURNACES ARE MADE, AND CERTAIN REMARKS THEREON

Ore-smelting furnaces are made from stones, or Adobes and mud; and, if he does not wish to lose his time and work, it is necessary that the knowledge of the Smelter-man begin with the selection of these Materials. Very hard stones with veinlets are not suitable for this work, because they crack with the heat of the Fire, and fly to pieces; neither will Limestone serve, because it will slake and break down to powder. Soft stones, with neither veinlets nor lime, resist fire the most; the best of these are of the kind called Whet-

stone (Sandstone).

The earth from which the mud, or Adobes, is to be made should be neither sandy nor salty, because either of these Properties, at a high heat, will cause fluxing, and for this reason furnaces are not built of bricks. The earth must be free from all such salts as Copperas, Alum, Saltpetre, etc.; and must be, at the same time, dense and fine. If there is an abundance of good crucible clay, the job may be made very lasting; at the least, when the furnace is finished it should be plastered on the inside with this clay. The Mazacotes (Furnace-bottoms), which are the sole-pieces or bottom of the furnaces, and the receptacles in which the melted metal is tapped, may be built in the same way, though some make them of a mixture of Earth and ground Charcoal in equal parts, called Carbonilla (Charcoal mixture). For reverberatory furnaces, suitable key-shaped Adobes should be provided, in order to facilitate and hasten their construction.



#### CHAPTER THREE

THE DIFFERENT KINDS OF FURNACES AND, FIRSTLY, THOSE IN WHICH FINELY GROUND ORES ARE ROASTED

Metallurgists have invented many furnaces of various forms for smelting and refining ores. In some furnaces, ores which may need it are roasted; in others they are roasted, preparatory to amalgamation; and in others they are smelted. Finally, in certain types the Precious Metal is separated from the Base, and in still another type the Precious Metal is refined. Ores are roasted in lumps or finely ground, and in either reverberatory or muffle furnaces.

The reverberatory and muffle furnaces of to-day have their foundations constructed in the same manner. The floor of the Reverberatory is built up to a height of a little more than a Vara and is of the Capacity and Size that may be required. It must be solid and perfectly level. The flame enters by a bridge located between two doors, as will be explained hereafter, and a fire-box is provided, with its necessary grate bars, for the burning of Wood and the separation of the Ashes.

The roasting floor of the Muffle Furnace is built on arches. The two main arches are three quarters of a Vara wide, and a little more than a Vara high; the rest of the arches are thin and built up with narrow Adobes. The distance between these small arches should be such that Adobes made of the same strong mud, one-third of a Vara square, or larger, and three fingers in thickness, will bridge over the space from arch to arch to make a level and smooth floor. Fire is lighted under each of the large arches, all the openings being closed, and thus the heat is communicated to all

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the floor space above the small arches, so that the finely ground ore thereon is roasted.

On these foundations is built the chapel or flat-arched vault; it must be flattened sufficiently to prevent excessive heat loss, but must still be roomy enough to accommodate a seated Workman to plaster it after smoothing off the floor. At the highest point of the arch, midway in the furnace, there should be left a hole or door, one quarter Vara in diameter, for charging the ground ore. On the sides there should also be left two holes in the shape of chimneys, for carrying off the smoke from the fire and the roasting ore. Furthermore, there should also be two doors, one-half Vara square at the floor line, and directly opposite each other, through which the ground ore can be rabbled and the progress of the charge watched. Through these same doors the charge is removed when finished. This is the type commonly used up to the present.

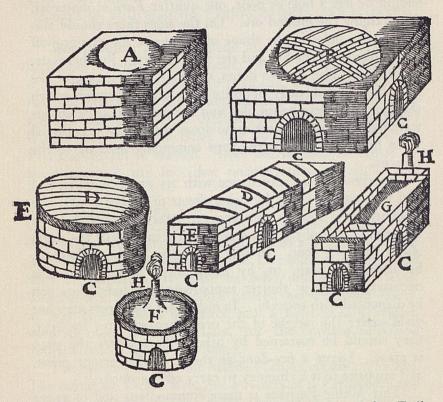
Nevertheless, in accordance with my practice, much fuel and time can be saved by using sheets of iron of double the thickness of a Real (a coin approximately one-eighth of an inch thick) and of the necessary length, instead of the usual Adobe roasting floor. In this way some of the arches can be dispensed with, or, by using Adobe pillars with the necessary longer or shorter supporting iron bars, they can be dispensed with entirely. In order that the sheets may not yield under the weight of the ore, when softened by heat, they should be sustained by other pillars where the span is great. Leave a fire-door at the most convenient point, and opposite to it a chimney to carry off the smoke.

This Muffle Furnace is more commodious and of easier construction if made rectangular instead of round, and one and a half times longer than it is wide. With the walls built in this proportion, all the iron bars supporting the sheets of the roasting floor will have the same length. In the middle of one end-wall, there will be left a fire-door, as in the long roasting furnaces. In the opposite and upper end, a chimney will be provided for carrying off the smoke.



A coat of mud should be applied to the lower sides of the bars and sheets, so that they will be less damaged by the heat; the upper side of the sheets should be plastered, so that neither melting Sulphur nor other things may come in contact with the iron and injure it.

These furnaces are entirely open on top, thus securing



prompt evaporation and speedy elimination of the Evil Substances the ores may contain. The surrounding walls are only half a *Vara* or less in height, this being sufficient to hold in the fine ore. In the arch of the Muffle Furnace previously described, the Evil Substances condense and fall back on the charge in an enlivened condition, to interfere later with treatment. The Rectangular Furnace is provided



with doors for removing the charge with rabbles, when it is finished.

A—Foundation of reverberatory roaster. B—Muffle furnace; floor built on arches. C—Fire-door; also serves for removal of ash. D—Grate bars. E—Foundation of round furnace. F—Round furnace. G—Rectangular furnace. H—Chimney.

#### CHAPTER FOUR

WHICH TREATS OF THE FURNACES FOR AND METHOD OF ROASTING LUMP ORES

Ores are roasted in lumps, either to facilitate grinding, or to remove interfering Evils which accompany them and hinder the treatment by amalgamation or smelting, as has been stated previously. They may be roasted in Reverberatory Furnaces, similar in every respect to those used in

smelting, as will be explained a little further on.

Lumps ores may also be roasted in Rectangular Furnaces, of a length greater than their width, provided with many small openings through which they may be fired, and the air may enter, as in those furnaces used for burning brick. Firstly, lay crosswise, on the floor, pieces of thick fire-wood (if at hand) in the form of a grill; then, on top of this, charge small wood, followed by the ore, the large pieces first, then the small, and lastly the fines. Where there is no fire-wood, *Yareta* and *Llama* dung or Cow dung may be used, together with some layers of grass, so that the fire will spread better.

Others roast ores with fire-wood or Yareta, using a squared place (Stall) of dimensions suitable to the quantity to be roasted. It is closed on three sides with earth or Adobes, having no opening; the fourth side is left open; the ore is charged on to the wood in a heap or pyramid. Water is added to the fines, to get a mixture like mud for covering the ore, leaving two or three holes for draft, however, as when burning charcoal.

If the ore to be roasted is a Galena, slope the bottom so that anything which may be fused will escape from the furnace and the fire, by running out of the furnace like a slag.

FUNDACIÓN JUANELO TURRIANO Ores are also roasted in large earthen Vessels, whose bottoms have many perforations; the lower part of each pot is let into another vessel containing Water, and thus the Sulphur or Pitch is recovered in the same way as already explained for the retorting of Quicksilver.

In addition, ores may be roasted in the same furnace used for the cooking process of amalgamation; the method is explained in a Chapter of the Third Book, and therefore I do not repeat it here. It must be noted that if ores which contain Copperas or Alum are to be roasted, the first thing of all to do is to remove these substances by washing, as explained before in the Second Book, dealing with amalgamation.



#### CHAPTER FIVE

ORE SMELTING FURNACES; AND, FIRSTLY, THOSE IN WHICH WOOD IS USED AS FUEL

Ores are smelted with either Wood or Charcoal. There are four modes of using these, in as many types of furnaces. When the flame of Wood alone is used, Reverberatories are employed; Wood and Charcoal together are employed in Pit furnaces. The heat of Charcoal alone is used in Muffle furnaces or *Tocochimbos*. And, finally, in the *Castellano* (Shaft) furnace, the ore passes through a bed of burning Charcoal.

It is best to build the furnace in a sheltered place, so selected as to have the least possible exposure to the wind. For a Reverberatory, build up a square Adobe wall of two and a half to three Varas or less on each side, according to the size desired, and one and a quarter Varas high. these walls swing a circle which shall touch the four sides; fill the vacant space in the corners with pieces of Adobe and mud. Fill the centre with good Earth, slightly dampened and well rammed, to three-quarters of the height of the walls. On this place the false bottom, made of material mentioned in Chapter Two of this Book; let it be dampened with water in such proportion that when it is squeezed in the hands it will be like a Snowball; it must not be dry enough to crumble, nor wet enough to be a mud. Throw in at one time all the lining needed, and spread all over the bottom of the furnace, in such a way that it will have the shape of a Cup or concave Fount. Ram well with wooden tampers or large stones; use large stones to smooth and shape the bottom so that it all slopes to a common point. After ramming and smoothing, this lining should have a thickness of at least four or five fingers.

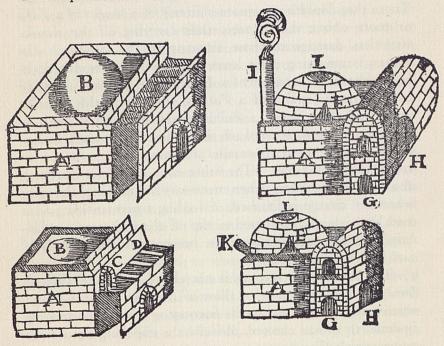
The Chapel, or Arch, is made round, like the ordinary bake oven, though not so high. On one side it has a fire-box and grate-bars for burning the wood and removing the ashes. together with a bridge through which the flame enters, in all respects like that described in Chapter Five on the treatment by cooking. In front of the fire-bridge and on the opposite side, leave some holes for the smoke; these may be partly closed at times (for other reasons) by Adobes, instead of being plastered up, according to practice in the smelters of the Provinces of Los Lipes and Chichas. In Turco they build up a square chimney to a height of a Vara or more above the furnace, thus carrying off the smoke with less damage to those assisting in the smelting. On the two remaining sides leave two flaring triangular doorholes, about one-quarter of a Vara to the side at the inside of the furnace, and half a Vara to the side at the outside; in one of these doors a Bellows may be fixed when it is desired to scorify or cool off the furnace; the same equipment may be used in smaller furnaces thus arranged to refine Gold and Silver. The other door is used for watching the charge, rabbling when necessary, skimming the slag when the charge is finished, or feeding when smelting on a lead bath; lastly, it is used to tap off the Litharge in cupelling, and through this door the bottoms or sheets of Gold and Silver are removed.

The roof of the furnace is not closed. A round hole is left, of sufficient size to allow a man to enter without squeezing, in order to lay the bottom on which the smelting is done, to spread the ore, to build the cupelling bottom, or whatever else is necessary.

Smelting is also done with wood in Pits. Make a round Excavation, more or less of the dimensions already given for furnaces. At the bottom, hollow out a number of moulds, so that the metal or matte will not all collect in a mass. Charge a layer of grass and straw on the bottom, follow this with the thickest of the wood, then the small wood; alternate the fuel thus in layers, until the pit is filled;



a hole must always be left in the centre, from the bottom up, so that lighted Coals may be dropped to the bottom to start the fire. The ore to be smelted will be charged on the top layer of wood. If it is convenient to dig these Pits close to a steep Bluff, tunnels can be driven, to make easier the lighting of the fuel charge; at the same time the melted Ore, as it runs out, is easily handled. This method of smelting is used in Las Chichas to obtain lead from Galena; it also serves for roasting Iron ores in the Districts where Iron is produced.



A—Foundation walls of the furnace. B—Furnace bottom. C—Adobe grate-bars. D—Fire-bridge. E—Furnace door. F—Fire-door. G—Door to control draft. H—Ashpit door. I—Chimney. K—Another door. L—Door in furnace roof.



#### CHAPTER SIX

# FURNACES FOR SMELTING WITH CHARCOAL

The furnaces in common use in three-fourths of the World for smelting all sorts of Ores are called Hornos Castellanos (Spanish Furnaces) in this Kingdom. Agricola mentions only this type for smelting. All are alike in construction, and they differ only in that, with some, the melted Ore flows continuously, while in others it is tapped at intervals, as explained further on. These furnaces are built Vertical, in the shape of a rectangular pillar, a little longer than it is wide. Some are a Vara in height; others, almost two Varas, and some less, according to the size of the Bellows available and the ease or difficulty of smelting the ore. The Tuyere, into which the Bellows pipe enters, is fixed in an opening in the furnace wall a little above the furnace bottom. Take note that the Tuyere nozzle must not penetrate into the furnace beyond the wall, because the Slag, falling on it, would be chilled by the blast, thus plugging the Tuyere. The furnace bottom is made from two parts of ground Charcoal and one of good Earth, well tamped. the bottom of the front of the furnace, which will be provided with a tap-hole for carrying off the melted ore to a Hornilla (Fore-hearth), built close to the furnace. that the slag may run off from the Fore-hearth, keep it well covered and heated with Charcoal, which will be lighted by the flame and blast from the tap-hole.

Others build round furnaces, though they are not so good as is pretended. They can be used, however, if care is always taken to have the wall above the Tuyere perpendicular; otherwise the melted Ore and Slag will plug it.

The natives of this Country, who have not yet gotten

to the point of using our Bellows, employ, for smelting, furnaces called *Guayras* (Wind Furnaces); the same are still used in this Imperial Village, and in many other Parts. They are like the aforesaid *Castellano* furnaces, but differ in having the walls perforated with many holes, through which Air enters when the wind blows, at which time alone they can smelt. From the lower side of each one of these holes there projects a piece like a small Ear, which holds lighted Charcoal, so that the entering air will be heated. They are placed on high locations where wind is usually blowing.

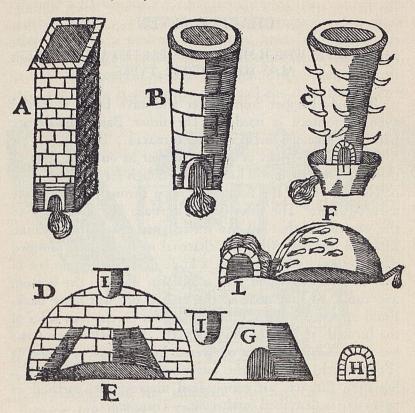
Furnaces like the Muffle Furnace of the Silversmiths and Assayers are called *Tocochimbos* in this Province, and rich ore, in small quantity, is smelted in them. The Indians

used them for refining only.

The Muffle furnace is made in the following manner. Build a small round furnace like a Reverberatory, but of scarcely a Vara in diameter. Let it have two doors; a small one through which can be inserted a Bellows nozzle if it is desired to hasten the work; the other opposite and large enough to take the muffle. This muffle is like the half of a big Pot split from the mouth to the bottom, and perforated with many holes to allow the entrance of heat from the burning Charcoal. There should be a space of eight to ten finger-thicknesses between the rounded part of the Muffle (Arch) and the furnace wall, to allow room for the charcoal. The mouth of the Muffle will be set flush with the furnace wall in the large door; if, however, the Bellows is to be used, the Muffle will be left open at both ends, and will communicate with the Bellows door as well. In the top of the furnace leave a round opening, provided with a burnt clay plug, through which Charcoal is fed as needed. The bottom of the furnace is lined with Charcoal mixture or a cupelling mixture, according to the work to be done, and on it the muffle is arranged. [Apparently the muffles used in Barba's time were not made with bottoms.—Translators.] Lastly, lute in a filler-piece of well-burnt Clay between the



Muffle mouth and the furnace wall. A clay door will be used in the mouth of the Muffle, so that the ore can be charged, the bath can be watched or cleaned, or whatever else is necessary may be attended to.



A—Square Castellano furnace. B—Round Castellano furnace. C—Guayra (Wind) furnace of the Indians. D—Tocochimbo, or muffle furnace. E—Large door for the muffle. F—Muffle. G—Clay door (Filler-piece?) for the muffle. H—Little door (Muffle door?). I—Plug for closing firing hole in top of furnace.



#### CHAPTER SEVEN

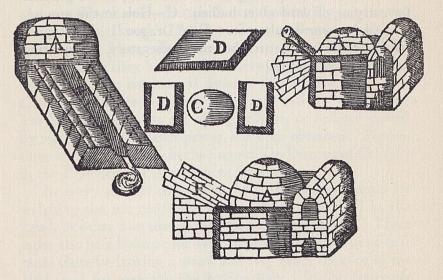
# FURNACES IN WHICH METALS ARE PARTED AND REFINED; ALSO SOME OTHER TYPES

To part Copper from Silver and save both, a special type of furnace is needed. The other Base Metals are parted in precious metal refining furnaces. Build a narrow furnace bed of bricks or Adobes, higher at one end than at the other, so that it will have slope enough for all the melted ore to run out of the furnace at once through a canal like a roof-gutter. The sides of this furnace bed also slope to the centre, so that all the melted ore reaches the canal. Line the bottom with good charcoal mixture, well rammed with stones or tampers; use a knife or other instrument of iron to smooth off and give a uniform slope to the bottom and canal, so that none of the melted ore will hang back. Build up small walls of ordinary Adobes on the four sides of the furnace, to hold in the charcoal. The melted ore flows out in the canal and is recovered in a Catino or Hornilla. (Fore-hearth) built at the lower end. [Barba refers to a liquating furnace, for copper-lead mattes; the method of operating is described further on.—Translators.]

Gold and Silver are refined in small Reverberatories, or in *Tocochimbos* (Muffle furnaces) when the material is little; the only difference is that a bottom of a cupelling mixture, put in as explained further on, is used instead of Charcoal and Clay.

There are other types of furnaces, which are, however, only modifications of those described. A very good furnace for smelting small quantities is called *Braguetilla* (Pit Furnace). Make a hole in the ground from one-third to one-quarter of a *Vara* in diameter, and proportionally deep;

line with well-tamped charcoal mixture as in the other furnaces. The side on which the bellows is placed is left open for charging ore and charcoal. The rest of the circle is built up with Adobes, and one is placed on top as a cover to hold back the fire. I have always used these furnaces to refine Copper. They are very appropriate for any work that requires a violent and strong heat. To the Reverberatories there is added, on the end opposite the fire bridge, a tail-like extension, which, on account of its shape and the amount of ore it swallows, some call the "Dragon." It is



not vertical like the aforesaid chimney, or a Castellano furnace, but inclined. Ore is charged into the "Dragon," and, especially when it happens to be Lead ore, there is no difficulty; it is easily melted by the fire and runs down to the charcoal mixture bottom, where it is held back and refined if necessary, or may be tapped at once if desired. [This type of furnace, known as Vaso, is still used in some parts of Mexico.—Translators.] A campaign in one of these furnaces will continue as long as there is ore, or as long as the furnaces and workers can stand it.

Also there may be built at the aforesaid part of the



furnace [As an extension of the laboratory.—Translators] a canal half a Vara in width, with walls on each side one third of a Vara high. This will be arranged as a furnace for parting Copper and Silver, and refining may be carried on [By liquation.—Translators] without charcoal at the same time as smelting. Fitted Adobes will be at hand for closing the top of the furnace as soon as the copper ingots [Matte cakes?—Translators] to be parted have been arranged in it. In its place this method of parting will be explained.

A—Furnace for parting Silver and Copper. B—Canal for carrying off lead-silver bullion. C—Hole in the ground. D—Adobes surrounding it. E—"Dragon." F—Copper refining canal furnace attached to reverberatory. [Liquating

furnace.—Translators.]



#### CHAPTER EIGHT

THE INSTRUMENTS THE SMELTER OF ORES MUST HAVE

After fire and furnaces, the instruments most needed in smelting are the Blowers. They are made in various ways and of different sizes, though the type ordinarily used is the common Blacksmith's bellows. In the Provinces of Las Chichas and Lipes, where the most smelting is done, from the beginning they have used blowers only in refining Silver, because all the smelting is done in Reverberatories. The Castellano furnace has been less used, and for this reason less Experience in the use of big bellows, or bellows moved by water-wheels or other power, has been obtained. Nevertheless, they are in use in the famous Tin District of Colquiri in the Province of Paria, close to Oruro.

In every smelter there must be a pair of Steel-yards for weighing the ore received, the ore charged, as well as the Lead, or other flux that it may be necessary to add. There must also be a Balance for weighing the Silver, and in no case must there be lacking a small and very exact Balance of the kind used for assaying the bullion bars. In the latter set of weights, the greatest weight will be less than an ounce; to it will be assigned the number twenty-four; to the second, which is one-half the weight of the first, will be given the number twelve; to the third weight, six; to the fourth, three; to the fifth, two; to the sixth, one. The seventh weight, corresponding to the half of this last, will again have the number twelve assigned to it; to the eighth, six; to the ninth, three; to the tenth, two; to the eleventh, one; and to the twelfth, the zero sign. Make these weights square and place them, according to their size, in a small box which will also hold the balance and a small pair of tweezers.

obviate a calculation for each assay, place the following table in the box. The first column gives the numerical order of the weights. The second the value in *Maravedis* [Units of fineness, not a coin.—*Translators*], as used in the assay of bullion bars, although the highest assay in use is 2380 [2400 corresponds to fine silver.—*Translators*]. The third column gives the corresponding value of the Silver per *Quintal* (100 Spanish pounds) of product assayed at the ordinary market price here of fifty *Reales* per *Marco* (Eight Spanish ounces) of taxable Silver. No account is taken of halves in any column.

Silver					Gold			
Weights	Assay		Value per Quintal		Carats	Grains	Value per Quintal	
1-24	2,400	M'vedis	1,250		24	0	22,500	Pesos
2-12	1,200	"	625	""	12	0	11,250	"
3-6	600	"	312	"	6	0	5,625	"
4-3	300	"	156	"	3 2	0	2,812	"
5- 2 6- I	200	"	104	"	2	0	1,874	"
6- I	100	"	52	"	I	0	937	"
7-12	50	"	26	"	0	2	468	"
8-6	25	"	13	"	0	I	234	"
9-3	12	"	6	"	0	$\frac{1}{2}$	117	"
10- 2	8	"	4	""	0	$\frac{1}{3}$	78	"
II- I	4	"	2	"	0	I	39	
12- 0	2	"	I	"	0	$\frac{1}{12}$	19	""

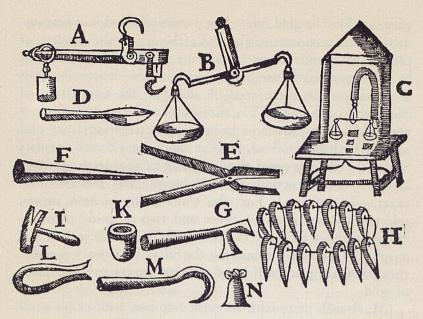
The master smelter should also have test pieces of Gold and Silver, without other alloy, which commence with pure Silver and end with pure Gold of twenty-four carats; the series rises by single points, making a total of twenty-five. He should also have a set of Copper and Silver which commences with pure Copper and ends with the purest of Silver. It is advantageous to have the twelve points indicating the fineness of silver and thus obtain another twenty-five test



piece set like the gold set. Any person who has had practice in these matters can easily make them. If the smelter of ores lacks confidence in himself he may entrust the work to any ingenious Silversmith; by using the delicate balance and weights just mentioned, he will find the adjustment of the proportions easy. The first point will be of pure Silver which has been proven to be such by cupellation assay and parting with Nitric Acid, so that there is no doubt as to its fineness. [At this point the author or printer seems to have omitted the instructions for making the test piece for one carat.—Translators.] For the third point of two carats, mix twenty-two parts of silver and two of gold. Proceed in this manner to make the other test pieces increasing the weight of Gold and diminishing the Silver by twenty-fourths; thus each test piece will be of as many carats as it has parts of gold.

Mark each piece with its carat number, and, in the same way, proceed to make the Copper and Silver test pieces. In addition to the foregoing, there should be the following tools: An iron ladle with a handle of the same material one Vara long, to which is fixed a wooden handle of a Vara and a half; this is used for feeding ore into the lead bath. when necessary. A hook three finger-thicknesses in length and about one wide, with its long handle of iron and wood for cleaning out slag. A tool like a chisel-bar, two and a half Varas long and two fingers in thickness, sharpened and pointed with steel at one end and drawn to a point for a length of three finger thicknesses. A tool called Hachuela (Hatchet) with its iron and wooden handle, as shown in the sketch; its use will be described further on. Big pinchers (tongs) for seizing bullion sheets, and hammers and chisels for cleaning off earth, and cutting up the bullion pigs. Tongs for dressing the assay fires and for handling the Callanas (Scorifiers) and crucibles. A stock of these latter vessels, as well as small Cendradas (Cupels), and the moulds for making them. Tamping tools, together with smooth and round stones for repairs to furnace and cupel bottoms.





A—Steel yard. B—Large balance. C—Small balance. D—Ladle. E—Tongs. F—Punch bar. G—Hatchet. H—Set of test pieces. I—Hammer. K—Crucible. L—Tweezers. M—Furnace hook. N—Chisel.



### CHAPTER NINE

# HOW TO PREPARE ORES FOR SMELTING

The careful sorting of ores before smelting is of the greatest importance, because that which melts and falls on barren material is held back and cannot get down to unite with the melted bath; it may at times be volatilized. If there is a lack of the necessary flux, the Silver will be so fouled and mixed with gangue that it cannot get free and will be carried off as the finest of particles in the slag; this I have seen not a few times in the slags of various smelters.

Roasting is a necessary preparation for the ores containing Sulphur, Antimony or Pitch, if they are to be smelted in Castellano furnaces with charcoal and blast; otherwise the violence of the fire will melt the ores before these substances are evaporated, and the Silver mixed therewith will go off in the slags. However, if they are smelted in Reverberatory furnaces, there is not so much danger of loss, as the charge gradually heats up at the same time these Evil Substances are volatilized before the ore melts, thereby inflicting less damage.

It will always be important to fine-crush the ores which have to be smelted in *Castellano* furnaces when it can cheaply and conveniently be done. The charge is thus more easily penetrated by fire, and the collector, or other aid to smelting, which should also be crushed, will all the better combine with the charge. In order that the flame [Blast?—*Translators*] shall not carry it off, the whole charge should be dampened with water.

Agricola explains with much detail how to wash (concentrate) ores before smelting. This is done very seldom

in these Kingdoms, except with Tin ores and, by a few, for washing out the clays from Lead carbonate ores. In the treatment of Silver ores, this ingenious but somewhat prolix method does not compete successfully with the amalgamation machine, provided a zealous effort is made to prevent the loss of Silver in the slimy water. It will be safer, in considering the ores suitable by nature for smelting, to exclude all those which are not massive and those mixed with much gangue or other sulphide ores; these should be ground and concentrated in tubs; the slimes are saved for amalgamation treatment, while the heavy part, settled in the bottom, will be suitable for smelting.



#### CHAPTER TEN

### THE COLLECTOR WITH WHICH SILVER ORES ARE SMELTED

Silver is begotten in ores so accompanied by things of contrary and opposite character to its own Nature that, in smelting, unless something is added to defend and collect, it is destroyed and consumed. Let him who cares to experiment melt alone a little of the richest Ruby Silver; if he urges the fire he will scarcely recover a trace of Silver, while if he melts with Lead he will recover three-fourths of its weight as very pure and white Silver. It might also be said (and I myself incline to this belief) that Evil Substances in the ores do not cause the trouble, but that there is a lack of some kind of cooking or moisture necessary to bring it to perfection (otherwise it would exist as White Silver); this lack is satisfied by Lead.

I am persuaded to this by what Raymond teaches in various of his writings; he solidifies Quicksilver with some medicines that he classes as of the lesser rank; such is the product that when it is charged on the lead bath in the cupel it is all converted to Silver; without this help of the Lead, the charge would be consumed and would disappear as smoke. These effects we should not attribute to Evil Substances in the mixture, because the material with which the Ouicksilver was solidified did not carry them; we should rather attribute it to the lack of the final stage in genesis, which Nature (either from lack of Time or for some other Reason) could not bestow. [The preceding, referring to Raymond's statements, is characteristic of much of the alchemist's jargon quoted by Barba.—Translators.] The proof of this, the same author states, is that the substances solidified by the Philosopher's Stone do not need this aid.

Ouicksilver bestows absolute perfection upon Gold and Silver, on account of their great affinity. Be the cause what it may, experience in all parts of the World, and at all times, has shown that the smelting of Silver ores with a gangue of stone or earth can only be done advantageously with a lead collector; this lead may either be associated with the Silver ores, or added in smelting Galena ores, refinery cupel bottoms, and lead oxide, all things which contain lead to serve as a collector. Only experience in the Art can teach one to know what collector is the most suitable for use with the ore to be smelted. The collector flux must smelt with the same difficulty, or with the same ease, as the ore; otherwise, if it does not melt or flow at the same time as the ore itself, the desired result will not be attained, and the aforesaid Inconveniences will be present in full force. The most active collector is used cupel bottoms, next Galenas or Lead ores; lying between these, and the easiest to use, is Litharge. All three collectors are used in the Castellano furnaces, but only Galenas in the Reverberatories; such qualities are sought in the Galenas as the character of the ore to be smelted demands. It is safer to melt the very rich ores on a lead bath, in a reverberatory or in the muffle furnace.

Ores to be smelted are mixed with things opposite in character to the Evil Substances they may contain [Sulphur, etc.—Translator]. These Evil Substances are named, and the method of recognizing them by their Fumes is given, in the Eleventh Chapter of the Second Book. The instructions there written down for roasting and amalgamation pertain more properly to smelting, and therefore much care should be taken in following them. To avoid repetition they are not set down here.



#### CHAPTER ELEVEN

#### THE THINGS WHICH AID IN THE SMELTING OF ORES

Not only does Lead, or a substance containing Lead, serve for a collector, as shown in the last Chapter; it also helps the ores of Gold and Silver to melt and flow. Lead, or leady substances, are of no advantage with base metal ores, because in the refining they are consumed by the lead.

In addition, there are various other compounds for facilitating the smelting of hard and rebellious ores, but they are of more use in assay work than in large-scale smelting, on account of their cost; for this reason no one in all these Provinces makes use of them. That which is called "Artifical Salt" is the principal flux in the assaying of ores; it is made by any of the following methods: First, equal parts of argols and vinegar are boiled until the salt crystallizes out, or one pound each of Llipita, (Pearl-ash?) or other strong ash used by dyers, quicklime, argols and melted salt are boiled with twenty pounds of urine until a third is lost; strain, and then add one pound and five ounces of salt and eight pounds of lye; boil together in a vitrified clay pot until the salt crystallizes out. Or, charge into a vessel salt and iron which has been lying in urine; cover with urine, close well and keep for one month in hot dung; at the end of that time wash the iron with the same urine and remove from the vessel; evaporate the liquid over fire until the salt crystallizes out. Or, finally, take a brine made up with equal parts of salt, soap, argols and saltpetre, and boil until it crystallizes. In order that the saltpetre may be suitable for assaying, it is prepared by boiling to dryness in a glazed pot with lime-water; repeat this operation until the saltpetre, when tested with fire, will no longer burn.

Another fluxing compound is made by adding to one ounce of white, easily melted, finely ground stone, four ounces of Litharge; melt in a crucible under a muffle; pour on a stone, and it will be like Glass on cooling; grind and save until needed.

Also, equal parts of argols, common salt and prepared saltpetre, well mixed, are heated together dry in a glazed vessel until the whole mass is white; finally, mix with an

equal quantity of Litharge and grind all together.

In addition to those mentioned, the rust and slags of Iron, lees of Wine, Vinegar and Nitric Acid used for parting Gold and Silver, all assist in maintaining the vehemence of the smelting heat. Pyrite, the mattes obtained therefrom, glass and its skimmings, salt, iron and its filings, copperas and easily melted sand are all useful. The ore takes up these substances and they defend the metal against the fire. Agricola cites other compounds in his Seventh Book, where they may be seen by anyone who so desires; nevertheless, there is but little, if any, necessity for their use, because since the introduction of amalgamation only ores easily smelted are so treated.



#### CHAPTER TWELVE

#### HOW TO TEST OR ASSAY ORES BY FIRE

To him who deals with ores, it is very risky not to enjoy the Good Luck of knowing how to assay and determine with certainty the values of those which fall into his hands. This advice has already been given to those who treat ores, and here I charge all Miners that they should learn to assay; this is especially necessary for those called *Cateadores* (Prospectors) who are occupied in hunting and discovering new mining districts. One should not trust to the amalgamation assay, as it is very deceptive, nor should one be persuaded by the judgment of Sight alone. Frequently the ore which looks like Lead contains much Silver, and that which is thought to be Copper encloses great riches. The rocks which are rich in one District, in another District will be poor, as well as the contrary.

Silver ores, which are the most sought-after and worked in this Kingdom, are the principal Subject of this Treatise. They and Gold ores are assayed in the following manner: If the ore is already ground, as when it is to be treated by amalgamation, mix it well, and then grab from all parts about three or four pounds; mix this portion very well and cut out from it what will weigh the same as the maximum weight in the assay set already described as being necessary. Mix this with an equal quantity of well ground and sifted Litharge; moisten with a little water, so that the mass will hold together when squeezed in the fingers. While the assay is being prepared, heat a scorifier, or, if none is at hand, a small hole in an Adobe or in the ground, lined with good clay. Build a wall of Adobes, or stone which the fire will not crack, in order to hold in the charcoal. When the

scorifier is well heated, that is, white-hot, place in it small lighted pieces of charcoal, and on them, in two or more lots as may be necessary, charge the assay; cover with more lighted coals and help with the blower. The Litharge will quickly melt and carry with it the Gold, Silver or Copper the ore may contain. When it is well melted, which is indicated by the slag being liquid like Oil, and when the bath is well cooked, as shown by the Lead beginning to smoke, remove the scorifier and cool.

Take out the Button, and refine in a small cupel previously heated for the purpose, until it gives what is called the Vuelta (Turn) at the time all the Lead disappears; this is recognized by the drops, like Oil, which flow on the surface of the melted metal until they touch the cupel and disappear in it; when these drops disappear they are followed by different colours called Damascos by smeltermen, on account of their similarity to the colors of the Damask plum. If the Button remaining in the cupel is Gold or Silver, it will be round, upstanding and bright, like the cleanest Quicksilver; if it contains Copper or some other metal it will be neither upstanding nor bright. Remove the Button as soon as it has set, but before the cupel has cooled; otherwise it is not easily loosened, and the bottom will be rough. the Button has Copper, determine the fineness with test pieces; better still, do not remove it from the cupel but add barren Lead, little by little, until the Copper is removed and the Gold and Silver alone remain.

Weigh the Button, after brushing and cleaning to remove any part of the cupel which may adhere. By using the table given in Chapter Nine of this Book, the value of a Quintal (100 pounds) may be ascertained. See which of the twelve weights balances the cupel button; the number following, in the column headed "Value," is the result sought. For example, if the button is balanced by weight number Nine, or number Three of the Second Order, the corresponding figure for value is six Pesos and four Reales; this is the current value of a Quintal of Silver ore of this assay. If the



balancing weight is number Three in the first column, the value per Quintal will be one hundred and fifty-six Pesos and two Reales, and so on. If the balance has to be made with two, three or more weights, then the sum of their values will be the value of a Quintal; thus, if the Fifth, Tenth and Eleventh weights were used, corresponding to one hundred and four, four and two, the value of the Quintal of Silver ore would be one hundred and ten Pesos and four Reales. [The discrepancies are due to the figures in the tables being approximations only. Examples cited include fractions of a Peso,—Translators.]



# CHAPTER THIRTEEN

SOME WARNINGS IN REGARD TO THE AFORESAID ASSAY OF ORES IN SMALL QUANTITIES

Do not be satisfied with a single Assay; make two on the same lot of ore, and if they are equal the assay may be considered correct.

The aforesaid Method, suited to the needs of the Prospector, is not the method for assaying Bars by melting in crucibles under a muffle. The necessary apparatus and space are not always at hand, nor is there time to heat the furnace; this is especially true in these mining districts where many are ordinarily occupied in seeking new discoveries. In the manner I have described, whatsoever the place and time, one may make Assays and they will come out very exact. In the twenty years I have practised assaying in different parts, I have never been mistaken in my Assays on very valuable lots of ore.

If there is a considerable quantity of ore to be assayed, and it is not ground but in lumps, pick out ten to twelve pounds of all classes; break it into very small pieces; mix well and cut out one or two pounds to be ground; on the

latter make the aforesaid Assays.

I have used none of the salts or fluxes described in Chapter Twelve of this Book. While these may be necessary occasionally, in order to make ore melt more easily, if it is ground and well mixed with the Litharge, no other flux is needed. And, even if the ore is very dry [Siliceous.— Translators] the addition of another part or two of Litharge will, without fail, collect the value the ore may contain. It will be sufficient for the miner always to be provided with this flux, which is very common; not everyone knows how

to make up the other fluxes. If the ore is exceptionally rebellious, add a little common salt, well roasted; it will

help the melting and clean up the slag.

The litharge obtained in refining Silver-copper ores is not safe to use in assaying; the coppery skimmings will contain some Silver. In any case, grind and sift well, and assay the litharge by itself; if it carries any Silver, subtract it from the results of the ore assays.

If the ore to be assayed is pure Ruby Silver, black ores (Sulphides of Silver) or tarnished Native Silver, do not grind it; crush to grain-like particles and charge on a Lead bath in the scorifier in the following manner: Weigh out twice as much lead as there is ore to be assayed, and charge into a well-heated scorifier; when the lead is melted and commences to scorify, charge the ore, wrapped in little papers, directly onto the lead bath, little by little; melt and refine [Cupel.—*Translators*] as directed previously.

Also, the lead used should be assayed for Silver; otherwise the results will not be exact. Deduct whatever amount

is found in the lead from the assay of the ore.

Take the same precautions in assaying Bar Silver to determine its fineness, and carry out the task as follows: Cut out a sample from the cupel pig or bar; weigh out what corresponds to the maximum weight given in the table in Chapter Eight, or two thousand four hundred Maravedis. Heat a capacious cupel and, when ready, charge on to it a quantity of Lead equal to the Silver. As soon as it clears up and begins to cupel, add the Silver. Let it cupel until the signs cited in the past Chapter appear; remove the clean Button and weigh again. The numbers on the weight or weights necessary to balance will indicate the assay in Maravedis, according to the said Chapter Eight. The greatest value assigned to bars is two thousand three hundred and eighty Maravedis. The difference between this and two thousand four hundred Maravedis [Theoretical fine silver of that time.—Translators] is considered to offset the volatilization or absorption loss due to unduly hot cupels;



very frequently the cupel absorbs Silver with Lead. The assay values are given in tens, and the units over each are reduced to the nearest multiple of ten; thus, in an assay which gives seventy, seventy-one, two, three or four, the value is put down as Seventy; but if it is seventy-five, six, seven, eight or nine, the value is given as Eighty, and so on.

# CHAPTER FOURTEEN

# SMALL-SCALE TESTS OR ASSAYS ON OTHER ORES

Lead should not be used in the assays of Copper, because it will be consumed and go off as a fume. The Copper ore should be well roasted in a scorifier after weighing; when the fire is forced, if the ore is rich, it will give up, as a Button, the Copper it contains. On weighing, the result will show the number of parts of it in each Quintal of ore. If the vein does not give copper abundantly, then, after roasting, the sample should be concentrated with care in a Chua (Batea), in the same way one tests amalgamation pulp. The lighter part, or earth without metal, will be washed off. The concentrate is removed and again heated by fire, this operation being carried out one or two times, or as often as may be necessary, until the Copper the sample may contain comes down as a cake, or Button. The operation is facilitated and shortened by using saltpetre and glass.

Also, after the first roast and concentration, there may be added an equal quantity of roasted salt, calcined argols and glass-skimmings; melt all together in a crucible (the best thing for this work) or in a deep scorifier, and the Copper cake will be found in the bottom. After the charge is well melted, do not allow it to remain long in the fire, or the copper will be burnt and consumed, and the assay result will not be exact.

If the presence of Gold or Silver is to be determined, in addition to the indications of the test pieces, the Copper button may be purified on a scorifier with poor Lead, in the manner already described. Eleven parts of Lead are necessary to scorify and cupel one part of Copper.

Galenas, or Lead ores, are also assayed in the aforesaid manner. Heat them without flux in a scorifier over lighted coals; if the ore is not much mixed with stone or earth. the melted Lead will easily come together in the bottom. Do not allow it to be overheated, or scorified. Cool, clean, and weigh the Button. Knowledge of the Art is necessary to avoid obtaining Crudio (Matte) which is brittle and rough; this happens when the fire has not yet consumed the Sulphur, Antimony or Pyrite mixed with ore. One may recognize the presence of Matte by the black appearance of the bath; it will not open up, and there will appear Flashes or Colours, like those occasionally seen in cupel refining, when the presence of Silver begins to be noted. Proceed with the firing until these signs are lacking, the bath clears up, and begins to scorify. An ore very difficult to melt may be mixed with Iron slag to heat the charge and facilitate the fusion; the lead will then form a Button and may be separated from the slag.

If the Silver content of the Lead is to be determined, the button may be refined on a cupel, and the calculation made for the quantity of Silver obtained.

Tin is assayed is the same manner as Lead, although it is best to roast, grind and wash the ore first; when the concentrate is well dried it may be melted. To determine if the Tin ore carries Silver, cupel on a well-heated bath of barren Lead; the spangled scum forming on the lead in the cupel should be removed with a stick as soon as it forms, until the bath clears up. Continue the firing until the Silver appears or all the Lead is consumed.

Iron ore should be heated in the strongest fire possible; roast well first, then grind, using a Loadstone to separate the iron from the rock. Collect all the material attracted by the Loadstone, mix with saltpetre, and melt into a cake.

Quicksilver ores should be ground and charged into a clay vessel, like a urinal. On this place a cover, with a long nose similar to an Alembic, dipping into a vessel of cold



water. Heat in a small furnace, and the Quicksilver, converted to a fume, will rise, fleeing the fire, be cooled off and consolidate in the top, whence it will flow to said vessel. Quicksilver ores may also be assayed in Retorts in the same way as floured or fouled Quicksilver.



## CHAPTER FIFTEEN

# SMELTING IN REVERBERATORIES ON A LARGE SCALE

Up to these our present Times, the smelting of ores in Reverberatories has been little used, or not at all, by those treating ores; and, although Reverberatories were known in the past, they were not of the perfected type used to-day, nor were they used for smelting, but for refining only. A sufficient proof of this is that Georg Agricola, who wrote so extensively on everything pertaining to Metallurgy, does not mention their use for smelting. Among the methods of smelting this is the most noble, and the most appropriate for ores of Gold and Silver, especially the very rich ones, such as the black Sulphides, Ruby Silver, Chlorides, the Steel-coloured ores and impure native Silver. These ores are melted on a Lead bath in the following manner:

On the false bottom, described in Chapter Five of this book, place another bottom or lining of the mixture there described; this, called Carbonilla, is a mixture of two parts of ground Charcoal and one of Earth; moisten and stir until it assumes the consistency already described, i.e., so that it can be squeezed in the hands like a Snowball. Charge into the furnace all the material needed for the lining; spread out and place all over the furnace bottom with the hands, in such a way that it has the shape of a bowl, or plate, the slope from all parts of the circumference to the centre of the lining being equal. Ram well with stones or large tampers; smooth and level off the lining with other small round stones or an iron tool. Close the round door in the roof at once with Adobes and mud; close the side doors also with Adobes, but not so tightly as to stop the draft and escape of the smoke. Build a wood fire and continue

to add wood as consumed, in such a way that neither is the flame suffocated in the furnace by an Excess, nor the furnace unduly cold for Lack of Fuel. Continue to fire in this manner until the furnace is white-hot inside, indicating that it is ready for smelting. Charge the pigs of lead at once through the door opposite to the bridge where the flame enters.

The Lead, when melted, is called the Bath. The quantity of Lead charged will conform more or less to the size of the furnace, the quantity of ore to be smelted, and its Richness. The ordinary practice is to charge two hundred pounds of lead for smelting one hundred pounds of rich ore; nevertheless, at Chacapa in the province of Chichas, I have charged into each furnace fifteen hundred pounds of lead to smelt six hundred pounds of rich ore from Trinidad Hill in Lipes. If the furnace is hot enough, the lead commences to melt at once, becomes bright and clear, like Quicksilver, and starts to scorify. Charge one or two ladles full of ore which is ready to smelt, after taking the precaution to break it up finely. The ore should not be charged in such small amounts that the bath is only partly covered; neither should it be heaped up. It is a lesser inconvenience to prolong the work by undercharging the ore than to roast the heaped-up ore, which may frequently contain objectionable substances. Stir the bath immediately with a long pole, like a sweep, so that all the particles come in contact with the lead. Proceed with the firing until the ore is well melted, which will be recognized by the slag being evenly fused and liquid. (Smelting is also done thus in muffles, in small quantities, with the use of charcoal.) Charge more Ore, pole, and allow time to melt; continue in this way until the work is finished.



# CHAPTER SIXTEEN

CONTINUATION OF THE METHOD OF SMELTING ON A BATH, TOGETHER WITH SOME WARNINGS REGARDING IT

The richer the ore the less Slag is produced. If there is much slag produced during the smelting, let it get well heated and liquefied without adding any more ore; then, using the hatchet, open a very small channel in the door, opposite to the bellows door, through which the slag can flow. If anything should block the channel, remove it, so as to not stop the flow of slag. Have at hand some balls of mud and ash for plugging this skimming-notch when desired; these are needed because occasionally a piece of the lining at the notch is carried away, and the sudden escape of slag may carry off some Lead and Silver unless the flow is checked. Skim off as much slag as possible in this way; it does not matter if the bath is not entirely cleaned of slag, because when there is only a little slag on the bath it is not injurious, but helpful and beneficial to the next charge. Skim the bath as many times as necessary, until the work is finished.

If the Lead bath is very much charged with Silver, it will not take up the Silver, in the ore which has been charged, with the same Quickness and Ease that it displays on the first charges. To determine this, remove a small ladle sample; cut off a piece equal to the heaviest of the assay weights; refine on a cupel and weigh. Thus can be determined the proportions of Silver and Lead in the bath. Unless the Lead is double the weight of the Silver, it will be necessary to add some. Make this test as many times as it may seem convenient.

When the ore has all been charged and well melted, skim

off as much as possible of the slag. The furnaces of the Province of Chichas are tapped with an iron bar through a hole which commences half a Vara below the door and terminates at the lowest part of the furnace lining. All the Lead and Silver in the furnace flow out through this taphole into a sloping channel marked out on the ground. When cold, the metal is broken up and guarded for future refining. Sometimes this River of Silver will flow fifty or more paces. In order that the melted metal may not spatter, place a quantity of grass or straw, or small pieces of fire-wood, at the point where the stream strikes the ground. The same thing is done with the large amount of lead produced in Galena smelting campaigns.

In Oruro, however, when the Bullion is ready to remove, all the doors of the furnace are opened and the coals are pulled from the fire-box, so that the furnace will cool quickly and harden the slag. As soon as the heat allows, the furnace is opened and the brittle slag is cleaned off with a hammer; the pig underneath is then divided, cut up with

chisels and saved for refining.

The greater part of the bath may be taken out in ladles and poured into moulds to cool, as is done at Oruro, thus obviating the losses incurred in the Province of Las Chichas when the metal is allowed to flow on the ground. The greater part of the work of cutting up the pigs is also

Assay a little of the lead, and the resulting silver will indicate the proportion of Silver and Lead in the bullion. He, however, who empties his furnace by the second method, may determine the proportion by assaying a dip sample of the bath. This will be exact, while assays made on different bars cooled in the earth will not be in accord; the bars which cool first, or those nearest the furnace, will contain the most Silver, while those farthest off will contain the least.



## CHAPTER SEVENTEEN

HOW GALENA ORES ARE SMELTED IN REVERBERATORIES, EITHER ALONE, OR MIXED WITH OTHER ORES

Silver-bearing Galena ores which contain enough Lead to smelt alone without any addition or other collector, even if the Silver content is low, are profitable to their owners on account of the Economies in smelting and the Rapidity with which the Silver may be recovered. In the Province of Los Chichas this class of mineral has been very common, and although the manner of smelting explained herein is generally in use, there have been, and still are, amalgamation mills treating the oxidized ores. When the furnace bottom has been put in place the charging is done as follows: If there are any large pieces of ore they are broken and reduced to the size of Walnuts or a little larger. The quantity to be smelted, frequently four or five thousand pounds, is scattered in the space between the four side doors of the furnace, in such a way that they are not blocked; this is so that the flame may enter and the draft be maintained for the exit of the smoke. A good part of the furnace bottom should also be left free from the charge, so that the melted metal can have a place in which to collect.

But if the Galena ore should be very dry and lack the necessary lead to fuse by itself and make the bath, mix it with a more leady ore in such quantity as the experience of the Master Melter may judge to be demanded, according to the greater or lesser Dryness of the ore.

The black and shiny ores of Silver are also smelted in this way, by mixing with Galena ores, though experience is necessary to determine their fitness, depending on the facility or difficulty with which they melt. With eight hundred pounds of black silver ore there is ordinarily charged three thousand pounds of Galena ore in the following manner: Place a layer of the black Silver ore in the four parts of the furnace already mentioned, and on it a layer of the Galena ore; follow this with another layer of black Silver ore and alternate thus until all the charge is in the furnace. It must be noted, though, that the charge should be topped off with a good quantity of Galena ore.

This is not a good way to smelt oxidized ores, even though they may be rich, because the accompanying Earth (Gangue) does not allow good melting, and there is danger of the Silver being lost as shots in the slag. Nevertheless, if for lack of Quicksilver, or for some other Reason, it is necessary to smelt, grind the oxidized ore and the Galena and mix them in the aforesaid proportion; knead with ordinary water (though if the water happens to carry Saltpetre it will be a help in the smelting). Make into loaves or balls, and when dry charge into the furnace, where they will be smelted with but little risk.

The ores having been charged in the way indicated, the upper door will be closed and luted; the other doors will be handled in the same way as in smelting on a bath, as previously described. Fire the furnace until the ore melts. At times it happens that the furnace bottom may not be well heated and hardened; therefore, the charge should be frequently stirred with a fire-hook (rabble) to loosen any part of the charge which may be sticking. Heat the charge until the Fluidity of the slag shows that it is time to skim, that is, until the slag can be drawn out into fine threads, like Taffy, after a small quantity is removed on a piece of iron or wood. Open the tap-hole with the hatchet in the manner already described, and through it will flow, little by little, the more liquid and highly heated slag on top. When the slag commences to flow sluggishly, plug the tap-hole and fire anew; do this two or three times. In respect to the other operations, carry them out as described in the Directions for Smelting on a Bath.



It is a common thing in the smelting of the black sulphides or other coppery ores, to find a layer of Matte on top of the lead and under the slag, caused by the accompanying Pyrite and abundance of Copper; this often happens with Galenas on account of the Sulphur therein. If there is much Matte it is saved; if little, it is charged on the bath during the refining.

In some parts bellows are used with these furnaces for forcing the fire. They are so arranged that the blast forces the flame down upon the bath, and in every way aids greatly, because Air is the great requisite which fortifies the

fire and makes it more active.

Whatsoever work is carried out in a Reverberatory furnace, one must be sure to have a clean flame; when it is dark and soots the furnace, it has no force and does not smelt. This may arise from a lack of Draft through the smoke-holes, and in this case can be remedied by opening them more, or it may happen because the ash-pit is filled to the grate-bars, preventing the entrance of air to liven and clean the fire; if this latter is the case remove the ashes, and the trouble will disappear.



#### CHAPTER EIGHTEEN

WHICH TREATS OF THE METHOD OF SMELTING IN "CASTELLANO" FURNACES

Charge the furnace with charcoal some hours before it is necessary to commence smelting, placing lighted coals on the bottom, or start the fire after charging, by putting lighted coals in through the tuyeres. Help with the blast, so that all the charcoal may burn, adding more if necessary, until the furnace is white-hot. Have at hand some wellcrushed slag, preferably Reverberatory, on account of its fusibility; then commence the smelting in the following manner: Using an iron bar, spread the burning charcoal in such a way as to close up all channels through which the ore might fall down to the bottom without being smelted. According to the size of the furnace, charge one or two shovels of the aforesaid finely broken slag, and on it charcoal. Blow forcibly, and keep the bellows constantly in The slag will melt, and the metal, if it contains any, will be released and collected in the fore-hearth at the bottom of the furnace. This fore-hearth should also be heated by filling with lighted charcoal. Alternately feed slag and charcoal until the furnace operates well, when the slag will be replaced by the ore to be smelted. Pull the slag from the fore-hearth with an iron hook, and charge pure Lead into the fore-hearth bath, if the ore being smelted should so require.

The campaign is commenced by smelting Slag, in order to glaze the walls and sole of the furnace, so that the Smoothness thereof will prevent the melted metals from hanging up; thus it is easier for the metal to descend and collect in the crucible. Notwithstanding that the aforesaid

practice is common to all ores, there are some which require special treatment; this is discussed hereafter, commencing with the ores of Silver and Gold.

Ores which may contain Gold and Silver and at the same time sufficient Lead to be self-fluxing, are melted by simply breaking to small pieces and charging into the furnace. If they melt too easily and form Matte in the fore-hearth, plug the furnace with a ball of clay and ground charcoal. Continue the smelting in this manner for some time, during which the bath will be refined. Tap the furnace, and the Lead and slag will flow into the fore-hearth. Plug the furnace again and continue in this manner until the campaign is closed.

If the aforesaid facility in melting is due to the abundance of Sulphur or Antimony, smelt them with Iron-bearing ores, such as those called *Chumpis*, to doctor up the charge, and both classes will the more easily yield up their contents. Should the ores be dry, or contain Orpiment, add others which are more easily fluxed and which abound in Lead, even if poor in Precious Metal.

Heavy lead ores and rich oxides are best smelted on a bath in a Reverberatory; however, should one desire to smelt them in a *Castellano* (Shaft) furnace, Sulphides which will yield much Lead or Litharge should be ground up and used as a collector. To one part of the well-crushed ore to be smelted, add two of the collector. Mix well with a little water, and, thus moistened, charge on to small coals or grass,

and proceed as before indicated.

Ores which contain much Lead and Copper, such as the black Sulphides, and copper Oxides, are also smelted with the aforesaid mix; however, before commencing the campaign it is necessary to charge sufficient poor lead into the fore-hearth to form a bath. This sucks up and drinks the greater part of the Silver which the ore carries. When the fore-hearth is full, pull out, with an iron hook, first the slag on top, and then the Copper which will be found underneath in the form of matte. Keep these separate. If the quan-



tity of Silver and Lead in the fore-hearth is sufficient, remove it partly or entirely by ladling into moulds.

If Ruby Silver or dull-coloured or shiny Sulphides are to be smelted in the shaft furnace (although the Reverberatory bath is the surest) grind and mix them up with water and litharge, because they are very easily smelted. Close the tap-hole at intervals, so that a bath of poor lead can accumulate to collect and cook the metal being smelted; or, construct the fore-hearth in such a way that half is inside the furnace and half outside; charge sufficient lead for the bath, and proceed as directed.

#### CHAPTER NINETEEN

# HOW OTHER ORES ARE SMELTED IN *CASTELLANO* (SHAFT) FURNACES

Of the ores of Copper, there are Pacos and Negrillos. call Pacos (Oxides) all green, blue, or orange-coloured ores, or any other colour whatsoever, unless they are steel-like or shiny. These latter I call Negrillos (Sulphides). Smelt the well-crushed Oxides in a furnace which has the tap-hole open all the time, and without using a lead ore as a collector. Aid the smelting by mixing in Copper Matte or Copper Sulphides, or a siliceous sandy earth, or certain white stones [Calcite.—Translators] which easily smelt. The pure Copper will settle in the fore-hearth, though at times, when there is but little depth to the bath, shot-copper may be mixed with slag. If so, grind the slag and separate the copper. Charge the rest back to the furnace and continue smelting until the slag no longer carries metal. One of the signs, in this and other cases, that the smelting is finished, is that the melted slag gives off no smell. [Of Sulphur?— Translators.

In smelting Copper Sulphides alone, it is necessary to close the tap-hole at intervals; otherwise, unless they are cooked in the furnace for a time, they flow forth as Matte. When the furnace is tapped into the fore-hearth, separate the matte which is on top when cooled, and return to the furnace.

Ores from which Lead is obtained are smelted in smaller furnaces; otherwise, it will be consumed and disappear as smoke. The sole of the furnace and the fore-hearth are made from earth mixed with Iron Oxide. The slags from lead smelting are of the greatest help in the smelting and

collecting of this metal, on account of their inherent properties. Let the tap-hole of the furnace be always kept open, and keep small coals constantly on the lead bath of the fore-hearth, so that it is covered and thus prevented from wasting. The furnaces can be small or large, according to the relative smelting rate of the ore handled. Litharge is very quickly smelted, and, in order to obtain all its lead, without losing anything as smoke, it is best to smelt in a small furnace, not more than twelve inches high, narrower at the bottom than at the top, and with a fore-hearth similar to other furnaces.

Tin ores are smelted in furnaces smaller than those used for Silver and other ores. They are not blown so strongly with the Bellows, because the Tin leaves the rock with only a moderate fire; with a violent fire the tin is calcined and turned to ash. Let the sole of these furnaces be of Sandstone, and if the walls are the same they will last longer. Sort the ore well, and wash to remove the earth or slime. Let the charcoal also be clean, because the small stones and earth often found in it foul the charge and cause much damage. In La Plata, where Tin is smelted, when the slag has been skimmed, the entire bath is covered with ground charcoal in order to prevent loss.



#### CHAPTER TWENTY

PRECAUTIONS CONCERNING THE FOREGOING INSTRUCTIONS FOR SMELTING IN SHAFT FURNACES

Do not charge large pieces of charcoal; if they descend to the tuyere they cut off the blast, and higher up they are likely to clog. The smaller pieces will then burn out, and ore will reach the crucible unmelted. Therefore, break up the larger pieces. Even with this precaution, it is well, before charging the ore, to poke down the charge frequently with an iron bar, thrusting it in from the top two or three times in order to fill up all the holes.

Take much care that the mouth of the tuyere, whence issues the Blast, be not plugged with the slag which may fall on it. When this happens the fire will lack force; the descending ore will not be melted; it will heap up and harden in the fire, and nothing will be accomplished until this is remedied. It may even be necessary at times to stop the work and remove the disturbance with a bar. Therefore, it is well to observe frequently if slag is cooling on the tuyere nose; and, if so, remove with an iron scraper. To prevent the slag accumulating on the tuyere, it is well to charge the ore in the centre of the furnace, and more to the side opposite the tuyere.

If the furnace should happen to be plugged (as it is said to be when the ore heaps up and hardens on the sole), clean out as much ore as possible through the tuyere-hole, using an iron bar. Stop charging ore, and in its place add slag, which, on melting, will moisten and soften the hardened (frozen) charge. Thus the charge will melt again, and the furnace will clean up, allowing the campaign to be continued.

On the side of the furnace opposite the tuvere, and a

little higher than the sole, I have been accustomed to leave a round hole, through which the hand could be inserted. This is ordinarily closed with a clay plug; but when the furnace becomes frozen I take out the plug and thus clean the furnace. This is better than cleaning it through the tuyere.

The charcoal on top of the furnace should be sprinkled frequently with water, in the same way that Blacksmiths do in their forges. Not only does this serve to hold back the fire; it also causes the condensation of the finer part of the metal volatilized by the flame, which otherwise would be lost. And it is for this reason that, in some Parts, tall and capacious chimneys are constructed over the furnaces; the Silver carried up by the violence of the flame sticks to the chimney walls, and after a time can be removed to advantage.

This method of smelting the abundant and very rich Black Silver and Ruby Silver ores in shaft furnaces with high chimneys has been used in the rich mining District of Porco since the discovery of this Country. Many times have I been in the smelting plants there, because the road from this Royal Village of Potosí to the Province of Los Lipes (where I resided seven years), passes through it. I know that a considerable recovery was made from the old chimneys.

When the task is about over, but before stopping, charge some litharge. This, on melting, will carry with it any Gold or Silver which may be held back in the charcoal or stuck to the furnace walls. To clean out the other metals, finish up with a slag charge. As the fuel level drops, and before the furnace cools, bar the walls free from Zinc and other crusts, using an iron bar with a chisel point three or four fingers wide.



# CHAPTER TWENTY-ONE

# THE METHOD OF SMELTING IRON ORE

The resistance of Iron ores to fire is so much greater than that of other ores that it has obliged those who occupy themselves in the treatment thereof to use greater violence (of flame) and force to reduce them and put them in condition for human use, for which they are more necessary than Gold or Silver. I have never smelted iron ores, and ordinarily I should not care to treat of this subject without considerable experimenting. This is the sole exception. Considering that in these Kingdoms there is an abundance of iron ores, and that Science may be needed in their treatment, I herewith set forth the method used (as I am informed by practical persons) in a part of the world (Spain) no less well-known for the Abundance of this most necessary Metal than for the Fame of the Nobility and Valour of its inhabitants.

The chunks, or large pieces, of iron ore are broken down to pieces the size of nuts or apples, so that the fire may the more easily penetrate the charge. Make a pit like unto that described in Chapter Five of this Book; arrange the wood and charcoal (as described) and on this mix and heap up the iron ore. Set fire to the charge, and, when half-melted, cool the furnace and remove the slag-like mass. Charge this mass into a furnace three feet high, and more than three feet square; line this with brasque to leave a crucible sixteen inches in diameter and eleven inches deep, more or less, according to the quantity to be smelted. Fill this chamber with charcoal; charge the ore on top, then more charcoal, followed by ore on top, thus forming a heap. Blow the fire very strongly with large bellows worked by water-

wheels. Take care in charging that the ore is placed on the side of the furnace opposite to the tuyere in order not to stop the blast. Continue until the ore is softened and forms one big cake; then remove the slag through the opening provided. When the smelting is finished and the furnace has cooled, pull out the cake with a pair of tongs. Knock off the adhering slag, and cut up with chisels. Heat these pieces again, and, with a great hammer moved by water, forge them into bars or sheets. Georg Agricola says to grind the iron ore very fine, mix with Quicklime, and then smelt in the furnace described, without the preliminary treatment in the pit furnace. Nevertheless, the method [Most?—Translators] used is that referred to above.



# CHAPTER TWENTY-TWO

# THE METHOD OF OBTAINING QUICKSILVER

At no time, nor in any part of the World, has there been such frequent use of Quicksilver as in this present Century and in this Province of the Indies. This metal is needed to amalgamate the Silver in the treasures of the rich Hill of this Village of Potosí, the most famous in the World; nor is this most fertile land lacking in its ore. Quicksilver is obtained in various ways, but all make use of the same principle, to wit, the ease with which the metal is converted by fire into a vapour, which, thereafter coming into contact with a cooling body, condenses and returns to its proper form, as we shall see.

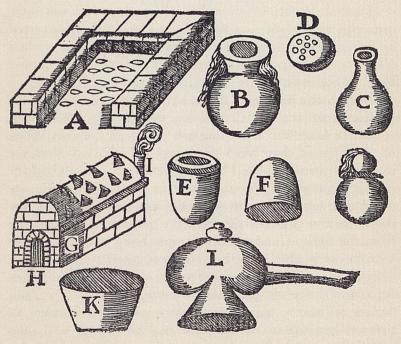
Bury many large pots in the earth, close together, in the form of a square. Enclose this square with a low wall of *Adobes* to keep in the burning fire-wood. Have other pots, of the shape of chamber-pots, wider at the bottom than the top. Fill them with well-broken quicksilver ore, and on the ore place a cover of pottery, copper or iron, which has many small perforations. Invert these pots and place in the mouth of the large pots sunk in the ground. Lute and fire from the top. The quicksilver vapour will condense in the bottom of the large pots from which it is removed later.

Quicksilver may also be obtained by retorting the ore in furnaces of the type used in all mining districts of this Kingdom for roasting slimes. They are arched furnaces, of greater length than width, perforated on the top and sides with large round holes in which to place the vessels of clay called retorts. The ground ore is charged into the retorts and covered with two finger-thicknesses of well-tamped ash. These vessels are covered with others called hoods, the joint being well clayed. Heat with a long flame through one

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end of the furnace; locate a door at the top of the furnace and at the opposite end, through which the smoke can escape. The Quicksilver will lodge in the top of the hoods, where it can be recovered. Should there be much Quicksilver, what falls back upon the ashes can be recovered by washing the ash.

The use of glazed stills (retorts) on iron bases, such as are used for retorting amalgam, is also an excellent method. In using all these methods, the Workers must always be on the windward side, on account of the great danger from the Fumes should they penetrate the vessels, or escape from a broken one. For this reason, and on account of their greater durability, it is best to use hoods of iron or beaten copper.



A—The square in which the pots are buried. B—Pots. C—Chamber-pot (Hood). D—Perforated plate. E—Retort. F—Hood. G—Flame furnace. H—Fire door. I—Chimney. K—Iron vessel. L—Condenser head.



# FIFTH BOOK

OF

# EL ARTE DE LOS METALES

IN WHICH IS DESCRIBED THE METHOD OF REFINING AND PARTING METALS

## CHAPTER ONE

THE METHOD FOR MAKING THE CUPELLING BOTTOMS FOR REFINING GOLD AND SILVER

The Gold and Silver issue from the furnace accompanied by a large amount of Lead (as will have been noted under the description of smelting) and also, at times, accompanied by other metals; and it is necessary that all these should be removed in order to leave the Gold and Silver with the desired fineness. With the aid of Lead alone, the other base metals are consumed and wasted; if there is not sufficient Lead to carry out the following directions, the alternative will be discussed later. To refine the Lead, it is necessary to prepare, in the following manner, what is called the cupelling bottom. First, have to hand a quantity of wood-ashany kind so long as it is free from earth, straw, or fine charcoal. It can be prepared by throwing the ashes into a tub of water and stirring well; on allowing to rest for a short time, the light substances will come to the top and can then be skimmed; the earth and small stones will settle to the bottom. Pour off the turbid water carrying the ash, and allow to settle entirely; then pour off the clear water and dry. The best ash, however, is that burned from Bones, as

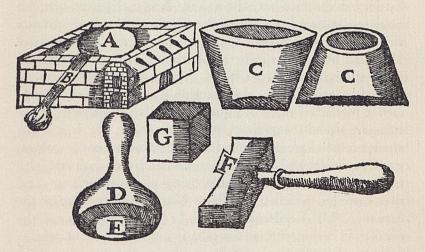
it is very dry; not always, though, is there to hand the necessary quantity of bones and facilities to prepare it. For this reason, the ordinary practice among smeltermen is to use the ash of Yareta (a low-growing Bolivian plant, generally used for fuel) or Cordones. The ash of Molle (a small Bolivian tree) or any other evergreen tree or bush is also good. Burn the material with care, in some clean place where the ashes will not be mixed with earth, and sift well to remove any part which may not be burnt to ash. Some mix with the ashes a portion of ground brick, so that the bottom will take up less lead and produce more litharge.

I found a kind of white earth in Oruro, on the hill called Tetilla, which saved me the trouble of collecting and preparing ashes, because from it I was able to make most excellent cupelling bottoms which absorbed lead as well as those considered the best. Charge into the furnaces one or two sacks full of ashes, according to the size of the furnace and the quantity to be refined; have the floor of the furnace clean and rammed hard; better still, mix on a blanket, throw on water, and knead with the hands until all the mass is equally moistened, and, as has been described before, until a handful can be compressed like a snowball. Clean and dampen the furnace bottom on which the cupelling bottom is to be placed. The furnace, as said before, should be a Reverberatory. Charge all the ash at one time through the round door in the top of the furnace; and let a man enter through the same door in order to place and shape the mass in such a way that there is room for all the lead to be refined. Tamp well, first with the hands, and then, standing upright, with the feet; follow this by tamping with stones and mauls as much as possible. Level off and smooth, so that, as the charge lowers, none of the lead carrying the gold or silver will be caught and held back. The deepest part of the bottom is inclined towards the door, placed opposite the bellows, in order that the litharge skimmed there will have the least distance to travel. This will be explained farther on. If calcined or ordinary salt is dissolved in the



water used in making up the bottom, it will be denser and stronger.

What are called Cupels are only small cupelling bottoms in which assays are refined. They are made in round moulds of iron or brass, greater in diameter at the bottom than at the top, shaped like a *Marco* (eight ounce) weight, and without a bottom, so that the cupel can be easily removed from the mould. Place the mould on a flat, hard stone, and fill with bone-ash, prepared as already described. Press first with the hands, then with the other part of the brass mould, having the shape of a pestle. In this way the cupel is given the necessary Concavity. Tamp the cupel with blows from a mallet or hammer, which should be ready to hand for this purpose. Remove the cupel and lay aside; the older and dryer the better they are.



A—The cupelling bottom. B—Litharge notch. C—Cupel moulds. D & E—Cupel mould. F—Mallet for tamping cupels. G—Flat stone on which cupels are tamped.



## CHAPTER TWO

#### HOW GOLD AND SILVER BULLION IS REFINED

When the cupelling bottom has been finished, close and lute the doors in the same way as when smelting ore. Heat the furnace well. If a crack should appear it can be remedied in this way; make a Sludge of ashes and water; tie a rag to a pole or furnace bar; wet this rag well in the Sludge and apply to the cracks; it will do no harm to apply to all the bottom. When the furnace is well heated, as is indicated by its being white-hot, the cakes, sheets or pieces of goldor silver-bearing Lead are charged through the door opposite the fire-box, and heaped up on one another. The Lead will melt and flow down into the concavity of the bottom, and commence at once to cupel. When the entire lot to be refined is melted, close the charging door. After the charge is well melted, if there is a quantity of slag, remove it, in the manner already explained under smelting. If but little, charge some charcoal on the bath, stir with a wooden rabble, so as to collect the slag in one mass, and then pull out with an iron rake. The bath now being clean, it will give off much smoke, which the bellows blast will force out of the furnace. The Lead continues to be consumed because the bottom takes up part and a part is converted into Greta, as Litharge is called. Litharge is like grease or oil, and is easily recognized by the difference between it and the bath on which it swims. The bellows blast pushes the Litharge towards the door on the opposite side, and when a sufficient quantity has collected a very small notch is carefully opened with a hatchet, in order to tap it out. As the level of the lead bath lowers, this notch is gradually deepened.

If there is much Copper in the mass being refined (by

reason of its presence in the ore smelted) a grease-like scum will appear on the surface, although it will be of a darker colour than the Litharge. Put it to one side, because it frequently carries with it much Silver. The smelters of Oruro always threw away this material until I went there and bought up these Wastes, or Slags, for a small sum and recovered some thousands of *Pesos* in Silver therefrom. To-day, however, from my example, they know how to recover everything. Let there always be two well-heated pieces of the bottom mixture alongside of the litharge notch, in order to plug it, should any of the rich Lead start to flow off with the Litharge. This condition can be easily recognized by any one, even if inexperienced, because the Lead looks like Quicksilver, while the Litharge is Reddish in colour.

The quantity of Litharge produced depends upon the violence of the Fire employed for the work. An excessively violent fire will not only prevent the Litharge from consolidating; it will even melt it and turn again to lead what has already been created. This Warning will suffice for the inexperienced, so that they may judge for themselves the heat necessary to maintain.

The Lead finally cupels off, and, as the saying is, there comes the turn to Gold or Silver. The mass becomes covered all over with a coloured film in which there no longer can be seen the drops of Litharge that previously swam on the bath. Cease to add wood, as the heat in the furnace will cause this film to clear up, and then turn to Blue and Rainbow colours, and finally to become clear like Quick-silver, just before the sheet solidifies. Before it grows cold, pry it loose from the bottom, using the wide point of an iron poker or bar. To do this, and to cool off the furnace more quickly, open the doors. Work the sheet toward the furnace door with iron bars, and finally remove it from the furnace with a pair of large tongs. Refining can also be done in Muffles in the same way, but on smaller quantities.



# CHAPTER THREE

# WARNINGS IN REGARD TO THE INSTRUCTIONS FOR REFINING GOLD AND SILVER

If, when the bath and furnace are well heated, the bath, instead of clearing up, remains dark and crinkles, it is a sign that it contains Tin, and it is useless to wait for it to be cleaned up by the force of the fire. Remove the scum with a long pole, and continue to do so as many times as necessary until the bath clears up. This is the sole Remedy. When the bath clears up proceed with the refining as directed.

Gold and Silver, either alone or together, show by the play of colours already described, that they have been refined. When they are mixed, the proportion of Gold cannot be determined until the sheet is removed from the cupel, sampled, and parted with Nitric Acid, as will be described further on.

If the sheet finished with some Copper in it, or was not well refined, this fact will be easily manifested even to the half-experienced. The bath will not clear up after the coloured film appears, nor will it become mobile and clear; on the contrary, it will become darker, and sometimes it will be covered, on cooling, with eruptions. This latter occurrence is also frequently observed after a sheet of bullion has set, when some of the litharge on the sides of the cupel is reduced to lead again. Add more lead, liven the fire, and proceed as before as many times as necessary, until the play of colour shows that the bullion is duly refined.

If the refined sheet of bullion should be unusually large, it will be necessary to tear out a part of the furnace at the front door in order to remove it. However, to obviate this drudgery, it will be best to remove part of the bullion as

balls in the following manner: Take the steel-pointed bar already described; wet, and insert to a depth of two or three finger-thicknesses in the bullion, immediately after the play of colours has ceased, but before it has set. Some bullion will stick; remove the bar at once and cool in water; again insert in the bullion, and repeat this operation until a ball of the desired size is obtained. Strike the balls with a hammer and they can be easily loosened from the bar. Continue this for the desired number of balls. Much work and trouble is obviated in this way when rich ores are refined on a large scale. In this I have had more than ordinary experience in the past years in the Chacapa refining furnaces at Las Chichas. With all the bullion sheets (and they were not a few) obtained from the ores of Trinidad Hill, Los Lipes, it was necessary to open the furnaces. The work was intolerable, not only on account of the excessive Heat, but also on account of the great Weight, as one sheet of fine Silver weighed two hundred and eighty-four pounds, while five others were only a little less. The show which I made with these enormous pieces of precious metal was not a little counterbalanced by the work it cost to get them out of the furnace, pack them to this Royal Village, and cut them up in order to make bars. Since then I have used the better practice of taking out most of the silver as balls; this is also the practice in the Oruro smelter.

A cupel bottom may serve for two or three refinings, if well made with a good depth of ash, and if it has not absorbed too much lead. Remove the bottom when convenient. The part which is hard, like a rock, on account of the absorbed lead, is called *Molibdena*, or *Cendrada*, by smeltermen. Place it to one side, and use it as a collector in smelting. Sift and save the rest of the ashes, which will be the best (obtainable) for other cupel bottoms.

If during the refining the heat rises to such a degree as to make the bottom and the bath the same colour, Silver will be lost. On account of the great heat it becomes unmanageable, and the cupel bottom becomes spongy and



sucks into it the Silver with the Lead; therefore the edge of the cupel bottom should always be darker than the bath.

The pieces of *Molibdena*, *Cendrada*, or lead-saturated cupel botom, when they are yellow inside like litharge, contain only Lead. If blackish, the bottom contains some absorbed Silver. Assay to determine the amount, and save (if justified).



#### CHAPTER FOUR

#### THE REFINING OF OTHER METALS

The base metals do not always come out of the furnace with the perfection they should have. Lead and Tin frequently come out rough and brittle on account of admixture with Mattes or other impurities. These impurities may be removed by placing the bullion sheets or pigs on wood or lighted charcoal on a slightly sloping ground, so that, when melted, the pure Metal will run off and leave the impurities behind in the ash. The pure metal can at once be moulded into appropriate forms.

The refining of Copper is even more necessary on account of its more general use, and because it cannot be beaten out if it does not possess the perfection due to it. Copper in the form of matte will break like glass; in some parts of Spain it is called Confrustaño. This is a mixture of Lead and Copper with Sulphur and other impurities, either created together in the mine or melted together in the furnace. Some persons roast the pigs frequently, and afterwards, in smelting with a strong fire, melt and purify until all the lead and other foreign substances are removed and the copper becomes refined. I, however, in refining many hundred-weight of this class of material in Oruro, eliminated the repeated roasting of the pigs, and at the same time recovered the contained Silver. Build a furnace of the type which I have elsewhere called the Braguetilla [Pit furnace.-Translators]. Fill with charcoal, light, and blow with the bellows until well heated. Charge pieces of the copper (or copper These will quickly melt with the violent lead?) matte. heat, and a great part of the impurities will be consumed, while the metal will flow down through the lighted coals. Add more matte and charcoal as necessary, and so proceed until the fore-hearth is full. Pull off the slag with a rabble. Continue the blast until all the matte is cooked and reduced to a clear bath which contains nothing but Lead, Copper and some Silver.

Remove a spoon sample and assay; if it contains considerable Silver, and there is not sufficient lead to part, add it in the proportions indicated further on. Allow the bullion to cool and lift out of the fore-hearth. If the Silver does not justify parting, and there is very little lead, proceed with the firing until the latter is all consumed and the bath turns to fine copper. To determine if the Copper has the desired fineness, thrust an iron bar into the bath; then remove it, with the copper sticking to it, and cool in water. If the copper adhering to the bar is clean and lustrous, like brass, it is sufficiently refined. If not, proceed (with the blast?) until the sample gives the desired Colour.

Should there be much Lead, it is best to let the bullion cool in the fore-hearth, though it may be removed and cast in pigs for further treatment, as will be shown later, in order to recover both Copper and Silver. In burning off much Lead, a considerable part of the Copper will also be lost.

These pigs of mixed Copper and Lead, with or without Silver, are spongy, like pumice stone. Roast them well, and then, with a chisel-pointed hammer, chip off the ash-like cap, which is Copper. This cap also carries some Lead and Silver. When cleaned, refine in the furnace as already described.

Iron may also be said to undergo a refining process when Steel is made from it. The process is thus described: Make a little round furnace, eleven inches or a little more in diameter, and eight inches deep. Line it with ordinary mixture of two parts of ground charcoal and one of mud or clay, well rammed. Let the sides of the furnace be of stones which do not melt nor splinter in the fire, or of half Adobes, in order to hold in the charcoal and pieces of iron charged on top. Fill with charcoal, light and blow well with the bellows, so placed that the nozzle reaches to the middle of



the furnace. Throw in at once some small pieces of iron ore mixed with that class of stone which will easily melt. (Calcite?) Blow strongly until all is liquid, like water. Then place two or three thick pieces of sheet or bar iron in the furnace and leave for five or six hours until well softened. Remove and draw out by forging on the anvil. While the iron is still hot, quench in cold water If, on breaking, the iron is white and evenly grained at the centre, it has been converted to Steel. If not, repeat the operation. When duly refined, draw out in the form of square bars, such as those ordinarily brought to us.

Quicksilver is purified by washing with vinegar and salt until the washings are no longer black. Then squeeze through buckskin, or wetted close-woven linen, or retort in the usual way. All the quicksilver caught in the upper vessel is pure, and whatsoever impurity it may have contained

will remain in the bottom of the vessel.



# CHAPTER FIVE

HOW SILVER IS PARTED FROM COPPER, AND BOTH RECOVERED

If considerable Copper is mixed with Silver, it will be necessary to part them, not only to recover the Copper, but also in order to obviate the excessive consumption of lead necessary for scorifying in order to recover the Silver. In scorifying off one hundred weight of copper, there are necessary at least eleven of lead. In the following method,

although lead is used, but little is lost.

Melt silver-bearing copper bullion with lead, in the proportion of three pounds of lead to one of copper. Cast into moulds of the desired size, although I have always made the pigs of a hundred pounds, or a little more, in order to manage well. Place the pigs on edge in the appropriate furnace, described in Chapter Seven of Book Four. Let the pigs be placed on square iron bars, or on pieces of bricks, three finger-thicknesses high, and on each side of the canal which runs through the centre of the furnace, so that they at no point touch the bottom or sides. Charge what the furnace will hold, leaving a space of five or six fingerthicknesses between the pigs, to be filled with charcoal. Cover all the pigs with charcoal, and light; in a short time, as the heat increases, the lead will begin to liquate, carrying with it the silver. The copper will not be melted. The leadsilver bullion will flow through the canal into the forehearth, from which it can be ladled into moulds to be refined later, as already described. The cupel bottom can be utilized, as before stated, on account of the lead contained as litharge. A little copper will also liquate with the lead, but it will chill near the tap-hole where the heat is less.

These chilled pieces are called "Spines" by refiners, and it is necessary to pry them out frequently, in order to keep the lead channel open. If any of the pigs should start to melt, pull the coals away; if there are any that do not liquate freely, apply more heat to them.

If desired, copper and silver may be parted in the Reverberatory furnaces already described, and used frequently by me. Arrange the pigs lengthwise in the furnace, on iron bars and pieces of brick, in such a way that an open passage is left in the middle of the furnace for its full length. Roof the furnace with adobes and mud, leaving a smoke hole at the end (opposite the fire-door). When the lead ceases to flow, it is a sign that the pigs are liquated. In order to prevent their melting, take off the adobes and let the pigs cool.

If the copper carries much Silver, it cannot all be removed the first time with the lead. Assay the liquated copper pigs, and if they contain much Silver, melt with lead and liquate repeatedly until all the Silver is recovered. Very little Silver will remain in the chilled material at the tap-hole, so it can be remelted as convenient.

Although the pigs (for refining) can be made in small scorifying furnaces, it is best to use Shaft furnaces in the following way: Have the furnace well heated, then charge in the copper; as soon as it begins to flow into the forehearth add the corresponding amount of lead, and continue to alternate these with fuel. Ladle the mixed metals into moulds for refining later.

If desired, Litharge may be used, without being first reduced to metallic Lead. It should be noted, however, that one hundred and thirty pounds of litharge are ordinarily produced from a hundred pounds of lead. The copper in the liquated pigs can be refined in the manner already described.



## CHAPTER SIX

# HOW GOLD MUST BE PARTED FROM COPPER

Although there are different methods of parting Gold from Copper, all depend on the resistance of Gold to Sulphur and other substances which easily alter and almost destroy copper. Hence, if gold-bearing copper is melted with Sulphur, or if Sulphur is well stirred into melted Copper, an earth-like mass will result. Again, thin sheets or granulated copper may be heated in clay pots with ground sulphur until the sulphur penetrates all the copper and makes it so brittle that it can easily be ground. If Quicksilver is ground into this material in the ordinary way, it will recover the gold. There is another way to part Gold from Copper, utilizing Heat and the reaction derived from the salt (Mixture) called "Artificiosa" (the cunning salt). It is made with equal parts of Copperas, Saltpetre, Alum and crude Sulphur, one pound of each, together with half a pound of sal-ammoniac. Grind the foregoing well and boil with one part of fullers' earth, one of quicksilver and four of common ashes, until reduced to dryness. Grind the residue and mix with one pound of ground litharge. To each pound of copper containing Gold, add in the crucible, little by little, one and a half ounces of this mixture, stirring it in well with an iron wire. Allow the crucible to cool; break it, and the Gold will be found as a little button in the bottom; the copper will be on top of it in the form of matte. Reduce the matte to copper in the way already described.

It will be easy for anyone who understands the Principles to find other ways. Sulphur, mixed with a little Lead, is all that is needed to alter the copper without detriment to the Gold, and therefore I am excused from writing about

other Methods, as the foregoing are not only sufficient, but are also best and most generally in use.

Some writers claim that Gold can be liquated from Copper by adding Lead, as already described in the liquation of silver and lead from copper in the last Chapter. I do not believe that they have ever tried it, having always doubted this on account of the Difficulty with which gold melts. The reason that silver can be liquated from copper with the aid of lead, is that both the lead and silver melt at a much lower heat than the copper. This is not true of gold; experiments which I have made confirm this statement.

If it is desired to remove gold from gilded copper, it may be done by heating the piece to Redness and quenching in cold water; the gold may then be removed by rubbing with a wire brush.

# CHAPTER SEVEN

THE NITRIC ACID WITH WHICH GOLD IS PARTED FROM SILVER

Gold which is either artifically or naturally mixed with Silver may be parted by using Nitric Acid, which is of an admirable activity, and one of the most curious things in human experience. A knowledge of it and its use is very necessary in this Kingdom in the treatment and parting of Silver, very frequently accompanied by Gold. In a matter so important it does not do to trust to the Sight, which does not allow the mixture of these precious metals to be detected, unless the proportion of the gold is considerable. Even if there is but little gold, it may be of great advantage to separate it.

The substances which, when distilled, have the natural Virtue of producing a Liquid that will dissolve silver, are Copperas, Alum, Saltpetre and Armenian Bole, Orpiment and Cinnabar. Various mixtures are made up to obtain the result, but those most commonly used are equal parts of Alum and Saltpetre, or two parts of Alum and one part of Saltpetre. Copperas and Saltpetre can also be used in the same proportions. When I have no glass vessels at hand for distillation, I usually add five or six ounces of drinking water to the mixture of one pound each of Saltpetre and Copperas, in order to provide for the initial absorption of the clay vessels.

First prepare the aforesaid materials in the following manner: Charge the copperas into a vitrified clay pot, and heat until it melts; stir well with a thick wire; then remove from the fire, cool, and pulverize well. The saltpetre is also heated over the fire, cooled and pulverized. The alum is prepared in the same way as the copperas, though some calcine it on an Iron sheet and then pulverize it.

The glass vessel in which these materials are charged is called, on account of the likeness, the chamber-pot. First coat the lower half, at least, of the vessel, with mud in this way: Make up a liquid mud, like porridge, from a good class of kneaded clay; wet woolen strips, or, if they are lacking, soak wool or clipped hair in the liquid mud, and apply as a thin coat to the retort. Let dry and repeat until a coating

of one finger-thickness results.

If the distilling furnace needs to accommodate but one retort, make it from adobes, about eleven inches square inside. Provide an ash door at the front, six to eight fingerthicknesses in width and proportionally high. At a point about eleven inches from the ground, provide a grate made from small bars or a perforated plate, in order to support the coals and at the same time to allow passage to the ashes. Leave another door above the grate for charging wood and charcoal. Build the side walls another eleven inches higher. Cover the furnace with a sheet of Iron supported by two iron bars extending from wall to wall. Let this sheet have four holes in the corner for maintaining the draft, and a large hole in the centre capable of receiving a clay vessel into which the glass retort is fitted. The clay vessel must be large enough to allow the glass retort to be set into it and packed around with sand or ashes.

Having ground and mixed (in the proportions indicated) the powders from which the acid is to be distilled, charge the retort one-third or, at the most, one-half full. Put on the hood, and lute the joint well with some strips of linen soaked in white-of-egg or flour paste, in order to prevent leakage. The nose of the hood is fitted into what is called the receiver, that is, a large flask, in which the distilled liquid is collected.

This is also luted to prevent leakage.

Light the furnace and heat slowly at the beginning until distilling commences; when the glass shows the colour (gas), increase the heat. Do this with such care, however, that



at least five minutes by the clock, or five bell strokes, and not more than ten, elapse between the falling drops. If the drops fall more rapidly there is danger of breaking the retort; if they fall too slowly the work is prolonged more than is convenient. Remedy the first condition by removing some of the coals with the tongs, and the second by augmenting the fire by adding small sticks of dry wood and regulating the draft. It will be well to cover the receiver with some cloth wetted with cold water, in order to condense the fumes with which it is filled. When the upper part of the retort shows white, it is a sign that the materials have completed their yield of fume. Hold back the fire until drops cease entirely; remove the coals from the furnace and allow the vessels to cool.



# CHAPTER EIGHT

CONTINUES WITH THE SUBJECT OF THE LAST CHAPTER; AND ADDS SOME WARNINGS IN REGARD THERETO

In place of vessels or chamber-pots (retorts) of glass for distilling the materials for Nitric Acid, even well-made vitrified clay vessels of the same shape may be used, with good results; it will be sufficient that the alembic and receiver are of glass. A number of these retorts may be placed side by side in long box-like furnaces built of adobes and bricks of the same type as those used for calcining slimes. They are all heated from the same grate. In this way an abundance of nitric acid can be obtained for the parting of Gold and Silver.

It is of much importance to know whether the Silver carries Gold, especially to those working in new and outlying mining districts. Even if glass hoods and receivers are lacking, it is well to know how, on occasion, to obtain some nitric acid, even if but little, in order to determine the Silver in the assays. The materials exist everywhere. It will suffice that the receiver be of vitrified pottery, such as a small jar, or vial, even if the vessel in which the material is distilled is not vitrified. Place tightly together the mouths of the vessels used as retort and receiver; lute and cover well; even if much liquid is absorbed, enough will be recovered for an assay which will give the desired information. Thus I did when I lived in Los Lipes at first, when that Province had but few Spanish inhabitants and there was a lack of all sorts of facilities.

Leave a hole, the size of a large iron Needle, between the retort and receiver; close with a small wooden Peg which can be removed if the fumes from the distilling compound become too powerful and dense. Thus the air imprisoned in the receiver will be cooled, the gases will condense more quickly, and there will be less risk of breaking the vessels.

When the Nitric Acid has been removed from the receiver, pour a little in a flask and on half a drachm of silver. When the silver is dissolved add a small amount of water; add more water, and in a short time the liquid, which at first appeared turbid, will become clear, and white sediment will fall to the bottom. Separate this sediment and save in another tightly stoppered flask or vial.

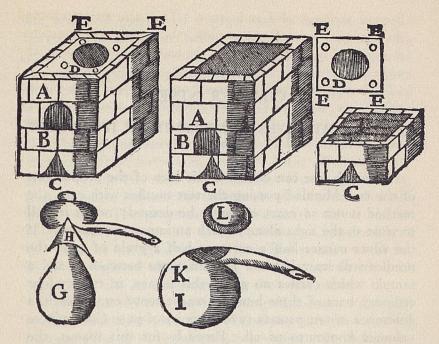
When the vessels are cold, remove from the retort the calcined and exhausted residue remaining after distillation; if very hard, it is best to add water, to avoid the risk of breaking the retort, and heat moderately in order to dissolve and

easily remove the material.

I invented a kind of vessel for distilling Nitric Acid, which is so well adapted for this purpose that I have continued to use it, and have passed it on to my friends. The best vessels for these distillations are long-necked glass retorts, because of the short travel for the fumes coming off from the materials; they, however, are inconvenient on account of the difficulty of filling and emptying through the long and narrow neck.

Make an imitation (of the foregoing) of good clay, and on top, before the clay dries, describe with a compass, and cut out, a piece the size of a crown, large enough to admit the hand easily; place four protruding buttons or knobs equally distant around the circumference of the opening. Bake and glaze both the retort and the piece cut out, which is to serve as a lid. Charge the materials through this handhole, put on the lid, adjust and lute so that the vapours cannot escape, fasten the cover with a wire which passes diagonally around the buttons, and connect to the neck. When the distillation is finished the materials can be removed with the greatest facility through the aforesaid opening.





A—Furnace. B—Fire-door. C—Door to ash-pit. D—Large hole in the sheet covering the furnace. E—Small draft holes. F—Grate bars. G—Chamber-pot (retort) of glass or vitrified pottery. H—Hood of the still. I—Longnecked vitrified pottery retort. K—Hole the size of a crown, in the top of the retort. L—Cover for this hole.



## CHAPTER NINE

HOW TO ASSAY SILVER TO DETERMINE IF IT CONTAINS GOLD

Although one can obtain a fair idea of the proportions of the two Metals by using the test needles with care, the method is not so exact as might be desired; nor is it well to trust to the sight alone in such an important matter. If the silver carries half a carat or half a grain of gold, the needles will scarcely show the difference between it and a sample which carries no gold; this means, in twenty-four ordinary bars of three hundred and twenty ounces each, a difference of ten pounds (avoirdupois) of pure Gold, whose value is known to us all. Precisely for this reason, the assay by Nitric Acid is necessary, in order to determine if there is an admixture of Gold, and in what quantity, in order to recover if sufficient. When the nitric acid is made the rest is easy. Proceed in the following manner:

Cupel the silver with a little lead in order to remove any copper or foreign metal it may contain, and so that

nothing but gold will remain with it.

If available, have ready a glass or a small china cup, though the best thing of all is a twenty-four carat gold cup. This I have used for many years; it lasts forever, and is damaged neither by ordinary nitric acid nor fire. It may be placed without danger directly on the coals, while the glass can only be put in the ashes. Beat the silver into thin sheets; cut them into pieces the size of a finger-nail and double them into cornets. Clean them well and weigh out the quantity to be assayed, taking the largest of the set of small assay weights. Place the weighed piece in the aforesaid cup and pour on Nitric Acid to cover. Put on the

fire and boil gently. If a glass cup is used, it may be necessary to add more boiling acid; with a gold cup this precaution is not necessary. So long as there is Silver for the acid to attack, bubbles of smoke will come off; when they cease, take the cup from the heat. If there is Gold it will be seen in the bottom as a black powder, or a residue like powdered brick. Pour the liquid into another cup; the Silver accompanies it. Wash the Gold with three or four changes of fresh hot water, and save, as it all carries some Silver; repeat this until the wash water is no longer cloudy. Drain at once, and heat the Gold in the silver pan, and weigh when cold. The proportion of Gold in the silver can be determined by the table in Book Three, Chapter Eight; the value of the gold in each hundred pounds of silver, based on eighteen Reales to the Castellano of twenty-four carats, can also be determined by the same table.

When the silver contains much gold, or when the gold contains some silver, it is assayed and parted in the following manner: First of all remove the copper from the bullion by refining with lead, in the cupelling furnace. Determine the fineness with test needles of gold and silver. If the proportion of gold is high, it will defend the silver against the desired action of nitric acid, and it will then be necessary to reduce the proportions to two of silver and one of gold; this really means that gold of a higher fineness is reduced to eight carats by adding the necessary silver. Experiments have proven this to be the best mixture to prevent the gold from being excessively divided, and yet, at the same time, allow all the silver to be dissolved. Let the silver which is to be added be assayed, in order to have the satisfaction of knowing that it carries no gold whatsoever; if it does, the assay will not be exact. For the rest, proceed as before indicated.

If the gold fineness is high and it has to be reduced to eight carats by alloying with silver, the quantity which must be added to each *Peso* weight of bullion of a determined fineness can be determined from the accompanying table, which



shows the *Pesos* ( $2\frac{2}{3}$  drachms) and *Tomines* ( $\frac{1}{3}$  drachm) opposite the fineness in carats. For example, if it is desired

Carats	Pesos (2 <sup>2</sup> / <sub>3</sub> drachms)	Tomines (\frac{1}{3} drachm)	Carats	Pesos (2 <sup>2</sup> / <sub>3</sub> drachms)	Tomines (\frac{1}{3} drachm)
24	2	0	15	0	7
24 23	I	7	14	0	6
22	I	6	13	0	5
21	I	5	12	0	4
20	I	4	II	0	3
19	I	3	10	0	2
18	I	2	9	0	I
17	I	I	8	0	0
16	I.	0			
	The State of the S				

to reduce twenty carat gold to eight carats, the table shows that one *Peso* four *Tomines* of gold-free silver must be added to each *Peso* of the aforesaid fineness. When melted together they will amount to two *Pesos* and a half of eight carat bullion.

However, it often happens that gold of a high fineness must be alloyed with silver which contains some gold. In that case the calculation must be made as in the following example: If it is desired to reduce twenty carat gold to eight carat, using silver which contains two carats of gold, put them down in this order: 20...8...2. The difference between 20 and 8 is 12; place it above the 8. The difference between 2 and 8 is 6; place it above the 2. The tabulation will then be:

I divide the first remainder (12) by the second (6) and obtain 2; this is the number of *Pesos* of silver, two carats fine in gold, which must be added to each *Peso* of twenty-carat bullion to reduce to eight carats. If, on the contrary, it is desired to raise two-carat gold to eight, with



high-grade gold of twenty carats, put the numbers down in this order:

6....12 2.... 8....20

Divide the first difference (6) by the second (12); the result is  $\frac{1}{2}$ ; therefore, to each *Peso* weight of two-carat bullion, half a *Peso* of twenty-carat bullion must be added to bring it up to eight carats. Other calculations are made in the same way.



# CHAPTER TEN

## HOW GOLD IS PARTED FROM SILVER

Gold is parted from silver in the same way as in Assaying, described in the last Chapter; the only difference is that for large-scale work the vessels and other equipment must be proportionately larger. The work may be carried out in glass vessels, though he who obtains vessels of fine gold will save much. I have been obliged to use gold vessels on account of the scarcity and cost of glass, and the risks attendant on its use, due to the frequent Breakage in this rigorous climate, even when the greatest care is exercised.

Take gold and silver Bullion, alloyed in the proportions indicated, and granulate finely; the less rounded the granules the better for the work. Or, the bullion may be beaten into thin sheets, cut into small pieces, annealed and made into cornets. Pour nitric acid over the cornets so that they are covered to a depth of two or three finger-thicknesses. Boil until all the silver is dissolved; this condition will be recognized by the sign already described under assaying. If

necessary, add more acid.

Lastly, transfer the liquid, in which the silver is dissolved, to a copper Kettle, adding an equal quantity of water. The silver will deposit at once on the copper vessel. If preferred, the diluted liquid may be transferred to vitrified Clay Vessels, containing some bars of copper on which the silver will deposit. The silver is all deposited when a cloth tape inserted in the liquid does not blacken or change colour. Or, a salt brine can be added to the liquid carrying the dissolved silver, and it will at once settle to the bottom. By any one of these methods the silver may be recovered. Dry the residue well before melting; if it has much adhering

moisture the surface will be blackened, and on melting it will burn and there will be some loss of silver.

By all of these methods the nitric acid is lost. He who cares to recover it, however, may do so by distilling the silver-carrying liquid, whereupon nitric acid with all its former strength will be recovered for a second use. The Silver will remain in the retort and may be melted, with the

precautions already cited.

The Gold which remains in the bottom of the parting cup is washed three or four times with pure water, or until the wash water is no longer cloudy. It is then dried, removed and melted with a little borax; or Corrosive Sublimate may be added to soften it, as is done by Jewellers (Silversmiths). The wash waters should be saved, as they also carry silver. They may be distilled, and the first portion which comes off will serve for washing gold; that which distils off after the coloured fumes begin to appear will be strong, and may again be used for parting.



## CHAPTER ELEVEN

# CONCERNING OTHER METHODS FOR PARTING GOLD AND SILVER

Although the most convenient and exact method of parting gold from silver is by means of Nitric Acid, not every one will apply himself to its distillation; nor are there always the necessary Elements for the large-scale work, as described in the last Chapter. However, in any case it is necessary to use nitric acid in assaying Silver to determine if it contains Gold, as has already been stated. There have been invented various other methods of refining Gold, all founded on the fact that its Purity and Lustre are altered with difficulty, while the other metals, on the contrary, are easily altered or contaminated. Even the purest Silver is so dulled and contaminated by Sulphur, and is thereby reduced to a substance so Black and Brittle that only a person very expert in these matters can tell it from a slag. Antimony does the same, because, as stated in the description thereof, it abounds as a compound of sulphur. Using these two materials, Silver and Gold are parted in the following manner:

Granulate the Silver bullion, and to each twelve ounces add two ounces and a quarter of well-ground unsublimed Sulphur. Mix well and charge into a new clay pot, well covered and luted. Heat gently, so that the Sulphur will melt and mix with the Silver, but will not burn. Remove the black Silver (Sulphide) from the pot; have ready three ounces and a half of granulated Copper for each twelve ounces of the original Silver. Charge the black Silver with half of this granulated Copper into a crucible; cover and fire until melted. When melted, add a spoonful of granu-

lated Copper and a spoonful of a mixture made with equal parts of Litharge, granulated Lead, calcined Salt and Borax; cover the crucible, and when the charge is melted add, in the order mentioned, the balance of the granulated Copper and composition. Through this operation the Gold will go to the bottom of the crucible, while the Silver will come to the top and be mixed with the copper-lead matte, mentioned before. To ascertain the depth of gold in the bottom of the crucible, insert a clay-covered iron wire and remove it at once. That part which is white indicates the depth of gold; the blackened part indicates the depth of matte and slag. When the charge is well cooked, empty it into a mould; the gold can then be easily separated from the matte.

Before removing the crucible from the fire, take out a little of the matte and cupel with lead; dissolve the Silver Button with nitric acid to determine whether the parting has arrived at the desired degree; if not, continue heating

the crucible.

The Silver and Copper may be parted and recovered in

the manner already described.

Sulphur also will separate Gold and Silver, though the procedure is somewhat complicated. Make a strong brine which will float an Egg, as described for the manufacture of Sal Artificiosa [This was apparently a stock flux.—Translators]. Boil powdered sulphur in this brine until it will melt over a naked flame, like wax, but will not ignite. When the sulphur thus prepared is mixed with melted gold and silver bullion, it will separate them.



## CHAPTER TWELVE

HOW GOLD AND SILVER MAY BE PARTED BY USING ANTIMONY AND CERTAIN OTHER COMPOUNDS

Melt eight ounces of Antimony and half an ounce of Copper in a clay crucible. Have ready three parts of this mixture to each part of bullion to be parted. Add a little of the Antimony mixture to the melted bullion; when melted in, add the rest little by little, waiting for each lot to melt well before adding more. Cover the crucible and allow to heat for as much time as one would spend in walking thirtyfive or forty paces. Have at hand a conical iron crucible (mould) greased and heated, and supported on a wooden foundation, in order to receive the melt. Tap the mould so that the gold will settle to the bottom. When cold, remove the Gold Button and melt again with the antimony mixture until the desired fineness has been attained; however, it will not be necessary to use so much Antimony as the first time. Finally, refine the Gold Button on a cupel. To the antimonial residue add an equal weight of Argols and half as much Borax. Melt the mixture on a piece of tile or in a clay crucible two or three times; any gold which may have remained will settle to the bottom as a Button which can be melted and refined like the first lot.

After this, add Lead to the antimonial residue and cupel the mass to recover whatever Silver it contains. If the antimonial mass is not re-melted with Argols and Borax, Silver will be lost in the cupelling.

Other compositions for parting gold and silver are made from Sulphur, Antimony, etc. The sulphur used is prepared by grinding well and boiling with strong Vinegar for six hours; it is then removed and washed with hot water. The first compound of this kind is made of one pound of the aforesaid Sulphur and two pounds of very well purified Salt. Another mixture is made of twelve ounces of Sulphur, six of Sal Artificiosa three of Red Ochre, and one of Minium. Another consists of half an ounce of Copperas, well dried over the fire, two ounces of Sal Artificiosa, four of Antimony, six of Sulphur, one quarter of an ounce of glass, one quarter of an ounce of Saltpetre, and one eighth of an ounce of Red Ochre. The fourth mixture consists of twelve ounces each of Sal Artificiosa, prepared Sulphur, and Shavings, and six of Borax. Still another consists of equal parts of the aforesaid Sulphur, Red Ochre, Saltpetre and Copper Oxide.

To twelve ounces of well-melted gold-bearing silver, add two ounces of any one of the aforesaid powders; stir very well and pour into another well-heated crucible which has been greased with tallow. Shake this crucible so that the gold will settle to the bottom; for the rest, proceed according

to directions already given.

Gold may be separated from pieces of gilded Silver, without detriment to them, in the following manner: Grind to a powder half a part of Sulphur and one part of Sal Ammoniac; grease the piece, dust with the aforesaid powder and use the tongs to place on well-lighted coals. When well heated, shake the piece over a tub of water, into which the Gold will fall, and from whence it can be recovered.

The same effect can be obtained by immersing the gilded piece in hot Quicksilver until well amalgamated. Remove and plunge into cold water, and the mixed Gold and Quicksilver will drop off. Repeat this as many times as necessary until there is no sign of Gold adhering to the piece. Squeeze and retort the amalgam in the ordinary way used for silver.



# CHAPTER THIRTEEN

CONCERNING THE PARTING OF GOLD FROM SILVER, OR ANY OTHER MIXTURE, BY WHAT IS CALLED CEMENTATION

Damages of great magnitude have been caused by that action which is called Cementation. Ignorance of this marvellous action on metals has caused the loss of great sums of Silver, because the Precautions given in Chapters Eight and Nine, of Book Two, were not applied. In the Cementation Process of parting, there is a burning of metals or alloys, against which Gold alone, by reason of its unequalled Nobility, is proof. Various materials enter into these Cementation compounds, the proportions cited by different Authors depending on their experience in refining gold. However, all the Elements of the compounds are mineral, and of the kinds which ordinarily accompany ores that are roasted before amalgamation; this is a proof of the Losses and Inconveniences before mentioned, because when the Silver is calcined it is easily dissolved; being dissolved, it is not recovered, and therefore the Metallurgists say that it was volatilized in the furnace and that the charge was overdone. In Ulphstadio's treatise on Alchemy, in the writings of Agricola, and elsewhere, are to be found Formulae of various cementation compounds. I do not consider it necessary to give them, because the ordinary mixture is easily made from ground brick and common salt, or rock salt, in the following way:

Take nine ounces of sifted brick powder and mix with three ounces of salt, using these same proportions on a greater or lesser scale, according to the quantity of Gold to be parted. Beat the Gold into thin sheets, like Escutcheons, or even thinner. Moisten the aforesaid mixture with strong vinegar in which has been dissolved half an ounce of Sal Ammoniac. Put a bed of this powder on the bottom of a new clay pot; on the powder place a layer of the gold sheets in such a way that they are not touching. Cover the gold with a layer of powder, and continue alternating thus until the pot is full or there are no more gold sheets. Frequently the gold sheets are wetted in a vinegar solution of Sal Ammoniac before charging into the pot. Cover and lute the pot well. Place it in a round or square furnace duly provided with grate bars and ash-pit. Heat evenly until redhot in all parts, like the retorts in which amalgam is distilled. Continue heating evenly so long as necessary, depending on the fineness of the bullion charge. Among jewellers it is accepted that bullion will increase one carat in fineness with each twelve hours' firing, but this is not infallible, nor is so much time always required. When the charge is thought to be finished, remove the pot and cool. Try the bullion with the test needles, and, if not totally fine, or of the desired fineness, charge the plates again with fresh powder and repeat the heating. The Silver contained in the bullion will be taken up by the powder, and may be recovered therefrom by the method given for the amalgamation of ores.



# CHAPTER FOURTEEN

# THE ACIDS WHICH DISSOLVE GOLD

The elements which, when resolved into liquids by distillation, have the power of dissolving Gold are Vitriol, Saltpetre, Sal Ammoniac, Antimony and Corrosive Sublimate; various compounds may be made from them. The first compound is made with two pounds of Vitriol and an equal quantity of Sal Ammoniac; distil in the same way as when making nitric acid, or take one pound of nitric acid in which silver has been dissolved and add three ounces of sal ammoniac; when dissolved, distil in a glass retort, and the resulting distillate will dissolve Gold; or use one pound of saltpetre and an equal amount of antimony, or equal parts of saltpetre, salt of urine or sal ammoniac. Raymond dissolves Gold in the Fifth Essence of Wine, highly rectified (with the help of a salt prepared from the same essence), in order to make his Potable Gold and the Stone so celebrated among Philosophers. However, the easiest method for dissolving Gold, and the one I have found most suitable, is to add one ounce of well-ground and easily dissolved household salt to each four or five ounces of nitric acid. The liquid totally loses its former force for dissolving Silver and acquires a violent activity against Gold (which it at first did not attack), converting it to a ruby liquid. This inspires the merited admiration of all who give due consideration to the reasons for these contrary effects.

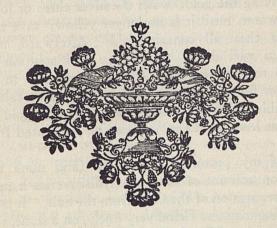
For many years, in these Parts, I have used cups of the finest Gold for parting Gold from Silver, as before mentioned, on account of the lack of glass and the risk in using it. On one occasion, when I was making an assay, the parting acid lacked strength; while it was still boiling I added a little

salt, which I happened to have at hand, thinking it might give greater penetration and be of help. No more Silver whatsoever was dissolved, though the liquid started to become vellow. At this novelty I paused, when I saw that the Gold was being dissolved. I have used this procedure many times since, in glass cups; it is both curious and easy. If there is but little silver in the bullion, it will settle to the bottom of the cup as a fine powder; if much, it will remain as spongy and brittle sheets or tubes. Pour off the liquid carrying the gold; wash the silver three or four times with hot water, until it is no longer vellow; save the wash waters, as they all contain gold. Afterward, melt the silver when well dried. Distil the gold solution if it is desired to recover the acid; if not, evaporate to dryness over a slow fire; the residue will be gold and salt. Melt in a crucible, using a strong heat, until the gold residue melts, or at least until the salt can be separated from the gold.

One of my personal experiences (and none the less esteemed on account of the greater discoveries it may lead to) is the separation of the Gold from the Salt. It is done in the following manner: Grind very finely, on a stone, the welldried vellowish gold chloride and salt residue; charge the powder in a glass vessel and cover with water-free, well-rectified alcohol to the depth of two finger-thicknesses. In a very short time the Fifth Essence will dissolve all the gold chloride and take on its vellow colour, though it will not dissolve the least quantity of the white salt. Pour off the vellow liquid and wash the salt once or twice with more alcohol until it remains white as snow, and the liquid is no longer discoloured. This Fifth Essence solution of Gold chloride will be sharp to the taste, on account of the copperas used in making the acid. It is a subject appropriate for Chemists, but one of which I am careful not to write. Even on previous occasions I have passed over this in Silence, in order not to embark on the pursuit and study of an Art which, though feasible and exact, has caused, and still causes, the greatest harm to



those who ordinarily exercise it without reason. Most rare in this World is it to find Persons who have obtained some advantage from their knowledge of the Art.



THE END



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